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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of 800 men. Its membership is divided into six classes, viz.:

A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

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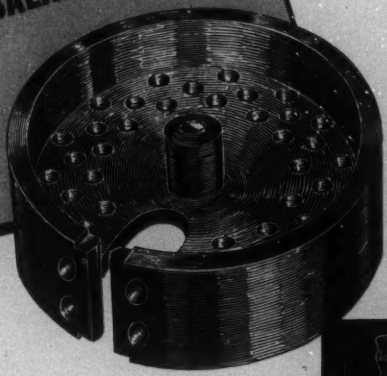

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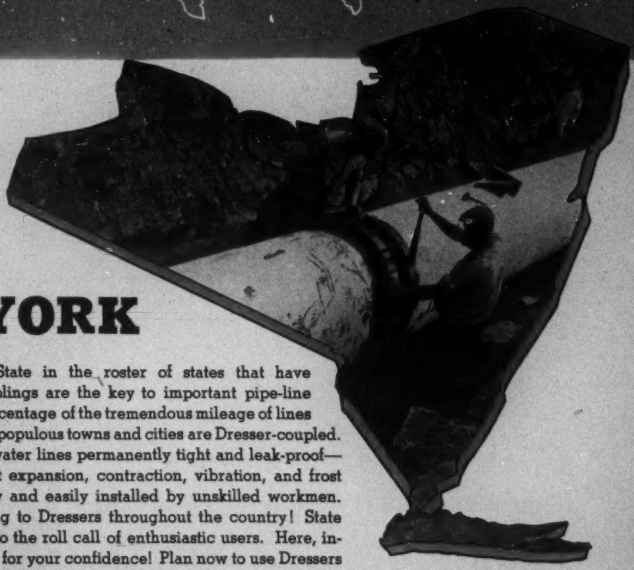

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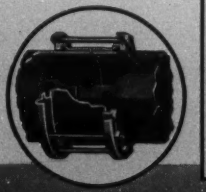

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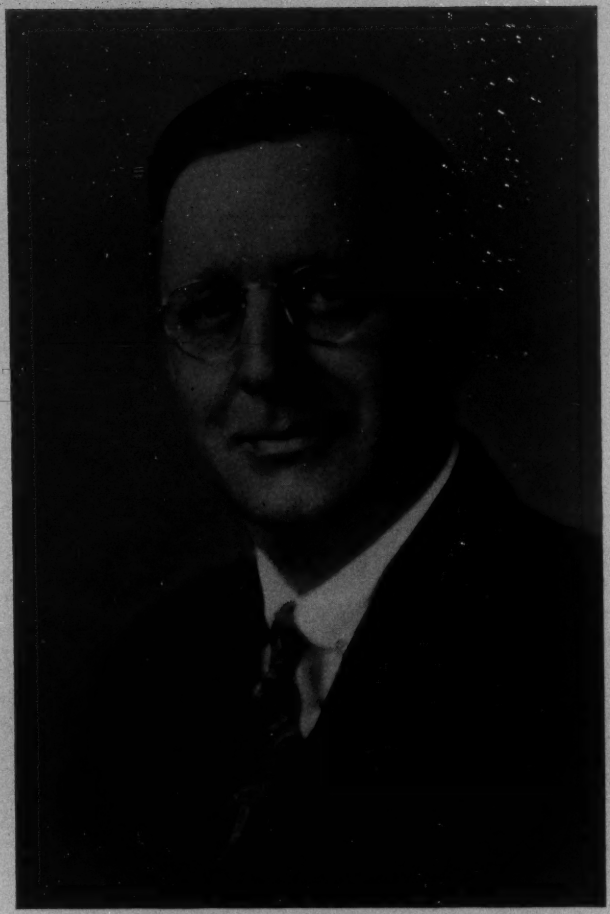

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FRANCIS H. KINGSBURY
President of the
New England Water Works Association
1941-1942

New England Water Works Association
ORGANIZED 1882

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WATER CONSERVATION IN NEW HAMPSHIRE

BY RICHARD S. HOLMGREN*

[*Read September 23, 1941.*]

The State of New Hampshire has shown a real interest in the conservation of its water resources since early colonial days. Legislative acts approving the construction of reservoirs and giving assistance to their development are found scattered throughout the state records. The latest acts in this direction were the establishment of the New Hampshire Water Resources Board in 1935 and of the Water Control Commission in 1937, both bodies being set up for the purpose of continuing the development of water conservation in the state.

The subject of water conservation divides itself into three parts: (1) the conservation of water for domestic water supply, (2) the conservation of water in lakes for recreational use, and (3) the conservation of water in reservoirs for river regulation and the generation of power.

The conservation of water for domestic water supplies will not be treated in this paper, as the Journal of the Association contains many admirable papers describing water systems in New Hampshire where water is conserved and utilized for domestic purposes. A collection would include papers by P. A. Shaw and his associates describing the work done in Manchester, a paper on the Concord water system by Percy Sanders, a paper by George Sampson and Robert Weston on the Keene supply, papers on the Nashua supply by William F. Sullivan and his associates, and many other papers. It is enough for me to say that these men and others are engaged in the conservation of water for its highest and primary use.

The conservation of water for recreational use has become a major problem in New Hampshire. The recreational industry has

*Chief Engineer, New Hampshire Water Resources Board and Water Control Commission, New Hampshire.

become the second largest source of income to residents of the state. People are coming into the state each summer in ever increasing numbers to enjoy the beauties of New Hampshire. These pleasure seekers come mainly from Massachusetts, Connecticut, Rhode Island, New York, and New Jersey, but in limited numbers from practically every state in the union. They stay for periods varying from a week end to the entire months of July and August. Originally, this summer vacation business was centered in the White Mountains and around a few of our larger lakes, such as Winnepesaukee, Newfound, and Sunapee. But now the demand for lake shore property has become so great that summer cottages are being built on even comparatively small ponds and on many of the old storage reservoirs normally drawn down in the course of the summer.

As the number of cottages on these reservoirs has increased, the friction between cottage owners and water users has also become greater. The water users who owned the dam at the outlet of such reservoirs have for many years drawn water to suit their own convenience and need and to obtain the greatest benefits for themselves. They are reluctant to give up this privilege and hesitate to agree to defer the use of the stored water until fall in order to maintain the water surface during the summer months at an elevation favorable to its use for boating and swimming.

Controversial reservoirs fall into two groups. The first consists of those that are entirely artificial bodies of water created by the construction of a dam across a stream or river that floods meadows and swampland above it. Before beginning work on the creation of such a reservoir, it was necessary for the water used to acquire, by purchase, all the land needed for the dam site and to arrange for acquiring all the land to be flowed. The reservoir, therefore, lies entirely on private land and the company has the same rights to the use of the body of water as it would have with any other private possession employed in its business such as a building. The abutting owners, or the general public, have no right in such a reservoir, except such rights of public way as existed for the original stream, if navigable, and they have nothing to say as to how this body of water is to be used so long as no nuisance is created.

The second group of reservoirs consists of those that have been created by erecting a dam at the outlet of a natural lake or pond. If

the lake had a water surface, in its natural state, greater than 10 acres in extent, it was a public body of water, and permission had to be obtained from the State Legislature before the water level could be raised. Ordinarily, permission was given without any payment being required. The only expense to the company developing the storage was the cost of the dam and the cost of the land abutting the lake which would be flooded. The old grants ordinarily contained no restrictions on the water users' right to utilize, as they desired, the water stored above the original lake level. Several court decisions in cases where this right was questioned were made in favor of the water user.

However, these bodies of water are still public waters, and the general public has rights in them. The present law defining public waters says this:

> "All natural bodies of fresh water having an area of 20 acres or more are public waters, and are held in trust by the State for public use; and no corporation or individual shall have or exercise in any such body of water any rights or privileges not common to all citizens of this state."

There is some question as to the status of bodies of water with surface areas between 10 and 20 acres, but it has been ruled that any lake or pond above 10 acres is a public water.

The New Hampshire Legislature enacted legislation in 1937 (Chapter 133) which designated the Water Resources Board as the Water Control Commission and directed it to study the question of lake levels on public waters and to try and devise steps that would correct existing difficulties. No powers were given that would make it possible for the Board to force dam owners to maintain lake levels. To date, the Board has tackled this problem by conferring with the dam owners and attempting to devise a method of operation that would result in the maximum gross benefits. In some cases, excellent coöperation has been obtained with the results that on a number of lakes, including Ossipee Lake, Suncook Pond, and Beaver Lake, satisfactory water levels have been maintained; and whereas, for many years, regular complaints were filed with state authorities from cottage owners on these lakes, during the past summer, which has been the driest on record, no complaints have come in from owners of property bordering these lakes.

The Board is continuing its work on other lakes and hopes to

obtain added coöperation from many more dam owners. It is probable that this coöperation will be forthcoming in a majority of cases. However, if it does not, it seems certain that in cases where the present method of operation causes a detrimental effect to the public in excess of the private benefits, legislative action will be taken to restrict the operation of the storage.

The Board has also conserved water for recreational use by rebuilding abandoned dams that formerly impounded reservoirs used for power storage and by creating new bodies of water that will be kept at a level best suited for recreational use during the summer. During the past year, three dams have been completed; one at Weare, creating a lake of 326 acres, one in Deering, flooding an area of 314 acres, and one in Kingston which creates a lake of 268 acres and in addition links together two other lakes making a body of water with a combined water surface area of 754 acres. For this work, no direct appropriation from the State of New Hampshire has been available. The money necessary to rebuild the dams has been raised by contributions from interested parties.

The conservation of water for river regulation was the main purpose for which the Water Resources Board was created. The conservation of water by the construction of reservoirs from which water could be released to increase the natural low flow of the streams has been practiced in New Hampshire since the earliest settlers built grist and saw mills on the rapids and at the head of the rapids built storage dams to conserve the water when not needed. Additional conservation was obtained by building dams across the lake outlet raising the levels from one or two feet to as much as ten to twelve feet. Later, as the demand for water increased, large storage reservoirs were built at feasible sites. However, in recent years the construction of storage reservoirs has slowed up as the more easily constructed sites were occupied, though regulation of the streams was far from complete and each spring saw millions of cubic feet of water pouring down the rivers to the sea without doing any work. This lost power was later made up by bringing into New Hampshire many tons of coal and barrels of oil to generate power in steam plants to supply electricity for the public needs.

In setting up the Board, the Legislature attempted to make feasible additional reservoirs by the use of state credit for financing and

by the elimination of taxes on all improvements. No direct appropriation was made which could be used for the construction of reservoirs, as it was believed that the reduction in annual costs due to the use of state credit and the elimination of taxes would make the projects economically feasible and attractive to water users downstream. They would then be expected to enter into contracts with the Board to pay annually for the use of the water an amount of money sufficient to pay for the cost of the project.

One project has been completed by the Board under this arrangement, namely, the Pittsburg Reservoir on the upper Connecticut River. This reservoir is now called Lake Francis in honor of ex-Governor Francis P. Murphy, during whose administration the project was constructed. The project consists of an earth dam 2,200 ft. long and 100 ft. high, creating a body of water of 2,000 acres and storing 4,000,000,000 cu. ft. of water. The reservoir cost about $2,300,000, and was financed by a bond issue of the Board which will be amortized over a period of fifty years. The water users downstream have entered into a fifty-year contract with the Board which calls for an annual payment by the water users of an amount in the aggregate sufficient to meet the expense of debt service, the operation and maintenance of the reservoir, and a portion of the administration expenses of the Board. At the end of the fifty-year period, the contracts will expire, and the State of New Hampshire will then own the reservoir without debt or obligation and the reservoir can then be used for whatever purpose then appears to be in the best public interest. The state will again be in possession of one of its natural resources which it has so lavishly given away in the past.

The next step in the program of water conservation has not been definitely determined. The work of the U. S. Corps of Engineers has been a deterring influence on the program due to the uncertainty as to which reservoir sites they ultimately will select for flood control use. The Federal Power Commission has recently entered the picture recommending that the proposed Hopkinton-Everett flood control reservoir on the Contoocook River, a branch of the Merrimack River, proposed by the Corps of Engineers, be abandoned and a power site directly above Henniker and a storage site further upstream above Bennington, be substituted. This suggestion also includes the installation of power-generating equipment at the flood control reservoirs

now being constructed by the U. S. Engineers at Webster on the Blackwater River and at Franklin on the Pemigewasset River, both branches of the Merrimack River. These suggestions are made as part of the great power expansion program urged by the Federal Power Commission to provide additional electric power for defense needs. The plan of the Federal Power Commission calls for the installation of 1,250,000 kw. yearly throughout the country during the period from 1943 to 1946, 45,000 of which would be in New Hampshire.

The Board believes, that in view of the present unregulated condition of the streams in New Hampshire, a better use of the proposed expenditures in this state could be made by using the funds to construct storage reservoirs and make additional water available to existing plants. In this way, very little demand will be made on vital materials or on equipment manufacturers who are at present having difficulty in meeting orders. An increase in the low flow of our rivers and streams would result in an increase in the base capacity of existing hydroelectric plants, thereby in effect increasing the generating capacity of the system without the installation of additional equipment.

The group of reservoirs proposed by the Board includes reservoirs on branches of the Merrimack River at Stoddard and Livermore Falls, raising of the existing Blackwater flood control reservoir, one reservoir on the Connecticut River at Indian Stream, and one reservoir on the Androscoggin River at Umbagog Lake. These reservoirs would add 679,000 acre-feet of storage to the three major river systems of New Hampshire. The water would be used through a total head of 539 ft. on the Merrimack River, 590 ft. on the Connecticut River, and 790 ft. on the Androscoggin River, making possible an annual additional output of 300,000,000 kw-hr. from plants on these streams or about 60% of the total power consumption in New Hampshire during 1940. The base capacity of the existing power developments would be increased by about 71,000 kw., this being obtained without the installation of any new generating equipment.

With these dams constructed and in operation, there would be available in the future, when the demand exists and the equipment manufacturers are able to supply equipment, the possibility of installing power-generating equipment at the Stoddard, Blackwater, Livermore Falls, and Umbagog Lake dams, with a total installed capacity

of about 75,000 kw. and the generation of an additional 150,000,000 kw-hr. annually.

It is impossible at this time to tell exactly what the next step will be in the program of water conservation and when it will be taken. It is our belief, however, that with the existing emergency some action will be taken soon. It is our hope that a program of additional conservation reservoirs will be developed to make available, without delay, the additional power that seems to be so badly needed at this time.

FLOW TESTS ON THIRTY-INCH STEEL PIPE, LINED WITH BITUMASTIC ENAMEL IN 1932

BY J. D. CARPENTER* AND GEORGE M. ROADS, JR.†

[*Read September 23, 1941.*]

During the year 1932, a steel pipe line ten miles long with an inside diameter of thirty inches was laid in rather rugged territory, in Schuylkill County, Pennsylvania. Flow tests conducted in 1933 over a period of three hours gave coefficients of friction up to 145.8 as shown in the following table.

TABLE 1.—VALUES OF COEFFICIENT "C" FOR 50,700 FEET OF 30-INCH PIPE LINED WITH BITUMASTIC ENAMEL LINING

	Length	Daily Rate of Flow—g.p.d.				
		2,160,000	4,084,000	8,165,000	9,994,000	12,093,000
1st	31,900 ft.	123.9	135.8	144.6	143.6	143.5
2nd	18,800 ft.	145.5	144.5	147.3	143.5	143.6
Total	50,700 ft.	130.8	139.6	145.8	143.5	143.4

These tests were reported in the Journal of the American Water Works Association, Volume 26, No. 1, January, 1934. The following description of this line is taken largely from the report of the tests made in 1933.

Character of Country. The first five miles of the line were laid down the east side of the Little Schuylkill River Valley, crossing a number of streams and many hills and gullies. The second half of the line followed, for the greater part, the State Highway, paralleling the Panther Creek Valley, and here the grades were much easier and the bends fewer. On the whole line there were 85 special horizontal bends with a maximum curvature of 70 deg. 40 min. and a minimum of 4 deg. 4 min. There were also 80 vertical bends with a maximum of 40 deg. 36 min. These bends were built of ⅜-in. steel plate welded usually in 4 or 5 sections with a center radius of 6 to 10 ft.

Details of Line Construction. The steel pipe was shipped from

*Gannett, Eastman & Fleming, Inc., Harrisburg, Pa.
†Superintendent, Panther Valley Water Co., Lansford, Pa.

the mill in 30-ft. lengths, with one longitudinal weld. In the field, three and occasionally four of these lengths were welded together and lowered into the ditch where a joint was made with a similar section by means of a bolted Dresser coupling with rubber gaskets. Bends of 3 deg. could be made with the Dresser couplings. In many places only 60 ft. (two sections of pipe) could be welded together before it was necessary to use another special bend. Along the line were seven 30-in. gate valves and 48 manholes. There were also approximately 100 additional connections to the line for air valves, drains, and a few connections to other piping systems.

On the first half of the line, over steep hillsides and valleys and through woods, large equipment to handle the pipe was not practical, and a certain amount of man-handling had to be done, which resulted in some damage to the inside and outside of the pipe. The enameling and pipe-line laying continued from July until December, 1932, with a range in temperature from 100 to 0° F.

Method of Applying Enamel. Immediately after the pipe was rolled and welded, the inside and outside was given one shop coat of Bitumastic priming solution before being shipped to a storage and enameling plant at Tamaqua, which lies about half way along the pipe line. Here the pipe was unloaded on a skidway and both the inside and the outside were given a second coat of Bitumastic priming solution.

The longitudinal welds on the steel pipe protruded on the inside usually about ⅛ in. and in some cases more. This made it necessary to apply a hand coat of enamel over the joint to be sure that the required thickness of enamel was obtained. Following this, the pipe was placed on rollers, and a trough containing the hot liquid enamel was inserted inside the 30-in. pipe for its full length. The pipe was then rotated at suitable speed, and the trough of enamel was dumped on the inside of the rotating pipe. To help speed the setting of the enamel, a stream of water was played on the outside of the pipe. The inside diameter of the steel pipe was 30¼ in., and as a minimum thickness of lining of 3/32-in. was required, the inside diameter of the enameled pipe is almost exactly 30 in.

The last six inches at each end of every 30-ft. section were not enameled at the plant, the enamel being applied by hand in the field, after the electric welding was completed. This meant that about 1 ft.

of pipe was hand-brushed and 29 ft. was machine coated in each 30-ft. length. The enamel on most of the pipe was very good, the surface being almost like glass or patent leather. The excessive heat of August caused the enamel on some of the pipe lying along the right-of-way to wrinkle or slip, particularly when the original coat of white-wash had been thin or had been partly removed in hauling and handling. This situation was remedied as soon as it was discovered by applying in the field a second coat of whitewash to the outside of the pipe.

Inspectors with miner's electric lights operated from storage batteries moved on low, four-wheeled, rubber-tired buggies through the pipe and checked over the inside lining after the line had been laid. On spots damaged during construction, the loosened enamel was removed, the pipe prime-coated, and, when the prime coating was dry, a 3/32-in. finish coat of enamel was applied with a hand brush. The area of inside camel, damaged from all causes, was less than 0.5 per cent. The inspectors worked in pairs, one inspector staying outside at a manhole to take notes, as they were called out, and to assist the man inside the pipe, as the steep grades, together with the smoothness of the lining, made it impossible, in many places, to crawl uphill on the inside of the pipe, even with rubber-soled shoes, and a rope had to be used to assist the inspector in getting up these grades. All coatings at the Tamaqua yard were furnished and applied by the Wailes Dove-Hermiston Corporation.

It is to be remembered that this line was laid in 1932, and so far as the writers know, it was the first large steel water line to which Bitumastic enamel was applied centrifugally. Improvements in the quality of the enamel and in the method of applying give to present-day pipe lines constructed in this manner a slightly better interior finish.

Test of 1940

On November 17, 1940, after eight years of continuous service, this pipe line was again tested and the coefficient of friction found to be between 144 and 145.

Method of Measuring Water. This pipe line carries water from Still Creek Reservoir to the Panther Creek Valley. At the time this test was made, the reservoir had in it approximately 1,400 m.g. of water

in storage and the million gallons consumed in making the test did not affect the water level. The water was measured by a Simplex Venturi meter, 30 in. by 12 in, located at the upper or dam end of the line. The line could not be entirely put out of service as it was in 1933, but the four consumers on the line between the dam and Coaldale—the end of the test section—were kept off during the period of test.

When the test started, about 1,250,000 g.p.d. was flowing through the line to Lansford and the uses of the Lansford area changed once or twice during the test. For the greater part of the time, however, they remained constant. Two blowoffs, just beyond Coaldale were used to vary the discharge through the line during the test.

Location of Pressure Gages. Gage No. 1 was located in the valve house, 600 ft. downstream from the intake tower in the reservoir. The take-off for this gage, however, had been moved since the first test in 1933 and is now 150 ft. below the Venturi meter in the valve house. This simplified the test somewhat, as it was not necessary to make any adjustments for friction losses through the Venturi meter. Gage No. 2 was in the Tamaqua Colliery meter house, which is located on the 16-in. line serving Tamaqua Colliery and takes off from the 30-in. line 31,900 ft. from the Venturi meter at the dam. The distance between the take-off point of Gage No. 1 and Gage No. 2 is approximately 31,750 ft. Gage No. 3 was located on the 30-in. line at Coaldale, 50,350 ft. from Gage No. 1. The line to this pressure gage takes off ahead of the Venturi meter at Coaldale.

Readings. At Coaldale, the most important point for the pressure readings, there were installed two pressure-recording gages, one of which had been calibrated and checked two days before the test. Both recording gages gave exactly the same readings throughout the entire test. At the valve house and at Tamaqua, pressure gages were installed that had been calibrated two days before the test was made, and these gages checked with the permanent gages installed at these points.

Two men were stationed at the dam, one man at Tamaqua, and four men at Coaldale. Readings were taken, at two-minute intervals, of the indicated rate of flow, the pressure, and the total flow through the meter. In the longer test periods, the indicated flow and the measured flow through the meter coincided almost exactly. In three

of the test periods, however, the indicated rate of flow gave higher results than the measured flow. During the two hours over which the test was conducted 1,050,000, gal, of water passed through the meter, while the average indicated volume was 1,076,650 gal. or 2½ per cent above the measured flow.

In 1933, 1,036,000 gal. were used in making the test, and the measured flow was from one to two points higher than the indicated flow. The difference between indicated gallons and measured gallons is shown in Table 2. If readings had been taken at 1-min. intervals, the variations would probably have been less.

TABLE 2.—INDCATED AND MEASURED FLOWS

Time	Indicated Rate— m.g.d.	Time— min.	Total Volume Indicated— gal.	Total Volume Measured— gal.
8.58 to 9.22	7.199	24	119,980	120,000
9.22 to 9.36	7.003	14	67,930	60,000
9.36 to 9.42	15.427	6	64,280	60,000
9.42 to 10.02	15.960	20	221,670	220,000
10.02 to 10.18	16.316	16	181,290	170,000
10.18 to 10.24	14.800	6	61,660	60,000
10.24 to 11.00	14.429	36	360,700	360,000
Totals		122	1,077,510	1,050,000

The indicated rather than the measured rate of flow has been used in determining the Williams and Hazen coefficients as the indicated rate gave more uniform results. The meter readings were in units of 10,000 gal. which are not close enough for an accurate determination in some of the shorter time intervals.

Table 3 shows the calculated coefficients for the different rates of flow. The lowest value of C is 145.5, the highest about 151, and the average 148.6. It is felt that the measured flow over the entire period was corect, and as this is 2½ per cent less than the indicated flow, a truer indication of the magnitude of C would be 148.6 minus 2½ per cent or 144.9. This is about one point above the value of C found in 1933 for flows of 10,000,000 and 12,000,000 g.p.d.

Our conclusions are therefore:

1. There has been no perceptible change in the Williams and Hazen coefficient C since the line was installed eight years ago.

TABLE 3.—OBSERVED HEAD LOSS AND CALCULATED WILLIAMS AND HAZEN COEFFICIENTS

Time	Pressure at Still Creek—Ft.	Pressure Loss to Still Creek Gage—Ft.	Pressure at Tamaqua—Ft.	Pressure Loss to Tamaqua Gage—Ft.	Net Loss—Ft. in 31,700 Ft.*	Net Loss—Ft. per 1000 Ft.	Williams and Hazen Coefficient
——	54.28	0.00	128.81	0.00	—	—	—
8.47 - 8.58	54.28	0.00	128.21	0.60	0.60	0.02	140†
8.58 - 9.22	52.55*	1.73	112.61	16.21	14.47	0.46	146
9.22 - 9.36	52.84	1.44	114.35	14.46	13.02	0.41	150
9.44 - 10.02	47.36	6.92	58.93	69.88	62.96	1.99	148
10.02 - 10.18	47.07	7.21	55.44	73.37	66.16	2.10	147
10.26 - 11.00	48.80	5.48	69.88	58.93	53.45	1.69	145.5

Time	Net Pressure at Coaldale—Ft.	Pressure Loss to Coaldale Gage—Ft.	Net Loss—Ft. in 50,400 Ft.*	Net Loss—Ft. per 1000 Ft.	Williams and Hazen Coefficient
——	183.5	—	—	—	—
8.43 - 8.58	182.5	1.0	1.00	.02	140†
8.58 - 9.22	159.4	24.1	22.37	.44	149
9.22 - 9.36	161.7	21.8	20.36	.40	151
9.44 - 10.02	76.2	107.3	100.38	1.99	148
10.02 - 10.18	71.6	111.9	104.69	2.08	147.5
10.26 - 11.00	94.7	88.8	83.32	1.65	147.5

*Obtained by substracting loss to Still Creek Gage.
†Assumed in order to get friction loss at beginning of test.

2. Unless something unforseen happens to the lining, the coefficient is not expected to change in the near future.

3. For design purpose a value of C = 140 can safely be used.

An examination made of the interior lining several years ago showed no change in its appearance except at some rough places in the lining where the action of the water made the enamel look as if it had been rubbed with fine emery paper. It was expected by the authors that the line would show substantially the same coefficient as it did in 1933. The water entering this line has always been chlorinated. This may have prevented pipe growths which we understand have occurred in some pipes carrying untreated water.

EFFECT OF EARTHQUAKES ON WATER DISTRIBUTION SYSTEMS

BY CHARLES GILMAN HYDE*

[*Read September 24, 1941.*]

General Statement. It may be reasonable to assume that severe earthquakes will eventually occur in practically every inhabitable section of the earth's surface provided the period considered is sufficiently prolonged. Present interest, of course, centers in the imminence and probable severity of crustal movements causing earthquakes, in the possibility of resulting damage to water distribution systems, and in the determination of the provisions which should rationally be made to prevent disaster in the event of such an occurrence.

Whatever the fundamental and intrinsic causes, it must be obvious that stresses exist in the earth's crust and that these accumulate to a degree where the strata are sheared, either initially or in repetition. Differential movements are thereby induced: sometimes horizontal, sometimes vertical; at times slow and uniform, at other times rapid and spasmodic. The more rapid movements may be classed in three categories: (1) volcanic disturbances, explosive in character, confined to regions of that type of activity; (2) shearing of strata under compressive stress, sometimes sufficient to tilt and fold them; (3) slippage of rock masses relative to each other on fault planes reaching to unknown depths through linear distances which occasionally may be very extensive.

Speaking in terms of relatively recent and frequent human experience, it is well known that earthquakes of significant severity are much more likely to occur in certain regions than in others. For example, areas subject to relatively frequent earthquakes of great violence are to be found around the rim of the Pacific Ocean and along the Mediterranean seas.

Within Continental United States the only area which may be said to be subject to severe earthquakes, in the duration terms of a

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human calendar, is California in its central and southern portions. This region is traversed by many faults, some of which are still active and some only recently, geologically speaking, become dormant. Recorded human history does not extend sufficiently far into the past to determine the periodicity of movement on certain of these fault planes. Some which may be thought to be non-active may again become active if and when the conditions of stability no longer exist. Still others are known to be definitely active and the time of future movement may be roughly predicted.

The superficial formations of the New England area are composed largely of older rocks brought to the surface by glacial denudation, with comparatively shallow subsequent alluvial deposits in low spots. There are, of course, many faulted zones in this rock structure. Some of these are local and of no great horizontal extent. But others are undoubtedly of comparatively great length and effect.

Because, in the short span of recorded human history in that area, few serious earthquakes have occurred, it has been surmised, and not without some reasonableness, that a fair degree of stability has been reached and therefore that earthquakes of destructive intensity need not be anticipated or feared. However, the catastrophic earthquake of August 31, 1886, in Charleston, South Carolina, sudden and presumably unanticipated as it was, may well serve to dispel any illusion on this point. Furthermore, Eastern United States and Canada were shaken with sufficient severity in 1925 to become a matter of record. And again, on November 18, 1929, the Atlantic Coast from New York City to Nova Scotia and Newfoundland was severely shaken although no great amount of damage was sustained except on the south coast of the Burin Peninsula, Newfoundland, where a tidal wave caused the drowning of 40 persons. The Charleston disaster caused 41 deaths and a property damage said to be in the neighborhood of $5,000,000.

It is understood that the subject of this paper was suggested by reason of a recent earthquake of noticeable severity in the New England area.

A widely employed principle of engineering design is that provision must be made for the unpreventable natural phenomena such as winds, rainfalls and earthquakes on the ground that, in nature, what has occurred once may occur again. To rationalize this matter repre-

sents a difficult problem, perhaps particularly with respect to earthquakes. Fortunately, it is believed possible to demonstrate that, as far as water distribution systems are concerned, good construction, following the best currently accepted practice, will not be subject to serious damage by even the most violent earthquakes which may be expected to occur, provided that certain special conditions are recognized and due precautions taken with respect both to construction and operation. It will be attempted herein to define those conditions and to suggest effective methods of meeting them. Thus will proper and adequate provision be made at no great additional expense for earthquakes as violent as any which have occurred in modern times in the populated areas of the United States.

Unfortunately the natural optimism of mankind and the real or fancied economic handicap imposed upon the designing engineer have all too frequently resulted in the neglect of adequate provision against such eventualities.

Sources of Information on Earthquake Effects. In this discussion it will be assumed that American experience, only, with earthquakes, as related to their effects upon water distribution systems, will be strictly pertinent and trustworthy. The reasons lie in the unique character of the materials, structures and equipment employed in American water works practice and, as well, in the extent and nature of the information available.

During the past 55 years, at least 4 earthquakes have occurred in the United States of sufficient intensity to affect water distribution systems. These were: (1) at Charleston, South Carolina, on August 31, 1886; (2) in west central California, in and around San Francisco, California, on April 18, 1906; (3) in Santa Barbara, California, on June 29, 1925; (4) in and about Long Beach, California, on March 10, 1933.

The writer has found in engineering literature no reference to the effects of the Charleston earthquake upon engineering structures, including water works, although no diligent search has been made. But detailed information of great value is available for the other and more recent occurrences.

General Effects of Earthquakes. It is recognized by all water works men that the provision for meeting maximum fire service demands entails by very far the major proportion of the cost of water

distribution systems in American communities. Were it not for this essential provision the capacities of mains, pumping units and other equipment and accessories would be relatively small as required to supply ordinary domestic and industrial consumption.

The possible damage to water distribution systems due to earthquakes, expressed in monetary terms, would be but a fraction of the probable loss by reason of a great conflagration such as that which occurred in San Francisco, California, as a sequel of the destruction of water works structures. In San Francisco, for example, 20,000 buildings were destroyed by the fire which lasted for three days. Of that number only 50 or 60 remained standing. The others were completely destroyed, with only an occasional brick wall in evidence. Unless one were an eye-witness, it would appear inconceivable that all materials which are made into the shape of buildings could be so utterly destroyed by fire. In this connection it is of interest to note that within 30 minutes after the earthquake shock, which occurred at 5:12 a. m., the Fire Department of San Francisco received notice of 52 different fires. It is probable that many others had started but could not be reported. The fire loss has been variously estimated between 300 and 400 million dollars. The actual earthquake damage to structures was obscured by the ensuing fire; but it was relatively small.

California experience indicates that major damage to water distribution systems may be caused by falling walls, as at Santa Barbara, which destroyed street mains, and everywhere by the shifting of poorly constructed buildings upon their foundations, causing the breakage or shearing of service pipes.

Earthquake Effects on Distribution Systems. Reviewing the experience in California with the earthquakes in the San Francisco, Santa Barbara and Long Beach areas, above referred to, the following general effects may be stated with assurance:

1. Pipes passing from firm to soft, loose materials will almost certainly be destroyed by shearing action or by the pulling of joints.

2. Pipes in soft materials subject to differential settlement may be locally sheared or may have their joints pulled due to such settlement or by reason of vibration alone.

3. Pipes crossing or following fault zones on which differential movement occurs will certainly be ruptured.

4. Falling walls from high buildings may produce depressions in streets, shearing the pavement and the pipe beneath.

5. Precaulked joints would appear to be less reliable than lead or cement joints in cast-iron pipe lines, cement joints being particularly satisfactory.

6. Cast-iron, steel and wire-wound wood stave pipe are all satisfactory as related to earthquake effects, provided they are in excellent condition to serve otherwise.

7. Valves and other accessories are seldom injured except when located on pipe lines under the conditions enumerated in 1, 2 and 3.

8. Service pipes without flexible connections to mains may be broken at those points as the result of vibration, particularly in soft materials, either dry or saturated, especially the latter.

9. Elevated steel tanks not especially designed to resist earthquake stresses will almost certainly be injured to the extent that the diagonal tie rods will be stretched and loosened and, if this action is carried too far, the tank may fall, particularly if the foundations supporting the legs of the structure settle differentially.

10. Well constructed steel tanks resting on firm materials with good foundations, concrete reservoirs likewise constructed, and distributing reservoirs with earth embankments will not suffer from earthquakes of the violence of those which have occurred in recent years in California.

11. Deep wells and turbine pumping equipment will not be injured if properly constructed.

12. Well constructed pumping stations and their equipment will not be seriously damaged if built in suitable ground on good foundations not located directly on the active fault.

13. Transformers and other equipment not anchored to floors may be shifted in position by vibration of the housing structure.

Provisions Against Serious Earthquake Damage. The more important provisions which should be made to minimize the danger and damage to water distribution systems and appurtenant works due to severe earthquakes may perhaps be listed as follows:

1. All main pipe lines, pumping plants, distributing reservoirs, including elevated tanks, etc., should be so located as to avoid threatening geologic faults.

2. Where main pipe lines must cross faulted planes liable to

differential movement, the pipes should be built with flexible joints on suitable supports in roomy tunnels or surrounding reinforced concrete structures.

3. Similar provisions should be made where important pipe lines must pass from stable to unstable materials.

4. Areas subject to serious disturbance by virtue of the type of formation in which pipe systems must be located should be so segregated as to make it possible to separate them from the remainder of the system without delay.

5. Valve controls should be generously provided for all main pipe lines and particularly as between dangerous and relatively safe formations, as defined herein.

6. All cast-iron pipe lines should be provided with well caulked lead or cement joints of maximum possible depth.

7. Foundations of all structures, such as pumping plants, elevated tanks, and the like, should be carefully designed and located in homogeneous material, preferably non-settleable but, if likely to settle, then of a sort which will settle uniformly.

8. Elevated steel tanks must be provided with ample tie rods or members of adequate cross-section strongly anchored to the main supports which they are intended to stiffen.

9. Hydrants should be located carefully to insure availability adjacent to areas where damage is likely to occur due to vibration or settlement or to the destruction of poorly constructed buildings.

10. Service pipes should lead from corporation cocks of heavy type and be provided with flexible goose necks at the mains.

Report of Committee of American Society of Civil Engineers. Immediately following the earthquake of 1906 in west central California, in and around San Francisco, the San Francisco Association of Members of the American Society of Civil Engineers organized a general committee and six sub-committees to study and report upon the effects of the earthquake and fire. Ten days after the earthquake the Association met in Oakland, San Francisco having been in large measure destroyed, and formed an organization for those purposes. An elaborate report of findings, with many contributed discussions, was published as Paper No. 1056 in the Transactions of the Society, Vol. LIX, December, 1907, pages 208 to 329, inclusive.

The following conclusions were submitted by the Sub-committee on Water Works:

"First—That greater attention in the future should be given to the avoidance, when possible, of threatening geologic faults, in the location of important water-works structures, than has sometimes been given in the past."

"Second—That skillfully designed and well-built earthen dams are structures proven by the great earthquake of April 18th, 1906, to be of great stability, and deserving of increased confidence."

"Third—That concrete dams of gravity section are able to withstand earthquake shocks of great severity without damage."

"Fourth—That distributing reservoirs, pumping machinery, elevated tanks and stand-pipes, if made secure as to foundations, and intelligently designed along lines of the best accepted practice, will be found capable of withstanding earthquake shocks sufficiently severe to work the general destruction of most buildings."

"Fifth—That pipe lines or conduits, of any character whatever, are almost certain to fail when intersected by a plane of large movement, whether that movement be in the nature of a faulting, or of a sliding or settling of the earth in consequence of earthquake shock; and that, in choosing locations for such structures, it is prudent, as far as practicable, to avoid localities subject to such movements."

"Sixth—That close adherence should be given to the recognized standards of the best present practice, such as the use in distributing systems of an abundance of suitably placed gates for isolating different pipes and different sections; the preservation of such gates in working condition; and having their location easily ascertainable, both in the street and from the office records; the duplication, along widely separated routes, of the critically important main supply pipes; the maintenance in as close proximity as may be to the centers of use of an ample storage supply of water; and the use of types of substantial design in working out plans for structures subject to possible earthquake shock."

Emergency Organization of Water Works Personnel. It is of vital consequence that water works personnel be organized and instructed with reference to disaster preparedness from whatever source such catastrophe may come. In illustration it may be stated that within a very few moments after the occurrence of the earthquake shock which caused such great damage in and around Long Beach, California, on March 10, 1933, the operating personnel of the Southern California Edison Company had pulled all electrical switches on conduits supplying the affected territory, thereby preventing loss of life and the possibility of fires caused by short circuits. The severity of this earthquake is indicated by the facts that 130 lives were lost and 50 million dollars worth of property was destroyed. School buildings in the area were notoriously destroyed and had the earthquake

occurred when the schools were in session the loss of life would have been appalling. Moreover, had the so-called San Francisco earthquake occurred later in the day, the loss of life would probably have been vastly greater.

It must be obvious that all communities and all utility organizations therein should develop a disaster preparedness program whereunder the responsible personnel is instructed as to how, where and when to report for duty and what to do under any and all critical circumstances.

Reviewing the story of the Water Supply of San Francisco, California, Before, During and After the Earthquake of April 18, 1906, and the Subsequent Conflagration, as told by the late Hermann Schussler, the distinguished Chief Engineer of the Spring Valley Water Company, a contribution dedicated to the Hydraulic Engineers of America, dated July 23, 1906, and prepared while all the facts of the case were fresh and vivid, it is of interest in this connection to quote as follows:

"Immediately after the earthquake occurred, at about 5:15 a. m., April 18th, finding that the telephone service had been interrupted by the earthquake, I started for the Spring Valley Water Company's pipe yard at Bryant street, between Fourth and Fifth streets. I met the head foreman, Mr. Gleeson, with his buggy, who was coming after me, and we found considerable difficulty, owing to the widespread conflagration south of Market street, to get to the pipe yard, where pipes, stores, repair pieces, horses, wagons and men are kept."

"Many of the company's men had reported there and were on hand to carry out any orders. The men were at once organized in squads and, under the direction of the several foremen, started out to discover the extent of the damage done by the earthquake to the main street pipe system and, wherever possible, to repair breaks, but, in such manner, as not to interrupt the flow of the water from the respective city distributing reservoirs towards and to the burning districts."

"As the telephone service between the city office and county reservoirs had also been interrupted by the earthquake, I started out at once to examine where and to what extent these main country conduit lines were ruptured. On the road I met my assistant, Mr. Lawrence, coming towards town to report to me what the various pipe walkers (one for each line) had reported to him."

* * * *

"In selecting the men to fill either or all of these positions, I have always placed the 'good character' of the men as the first and foremost requirement. After that came energy, adaptability and skill.

"Thus I soon found out for what specialty a man was best fitted. If, thereafter, he fully came up to my expectations, he was regularly employed at fair pay,

and, when his qualifications permitted and the opportunity offered itself, he was advanced in position and salary.

"Having steadily followed this method, for fully four decades, of carefully selecting, thoroughly training and properly treating our employees in the Engineering, Construction and Maintenance Departments, I can say, from the bottom of my heart, that the splendid physical condition of our very extensive works, even after the earthquake (which works show an endless variety of constructions best adapted to the climatic, physical and local circumstances), is largely due to the faithful work of every man that has helped me to construct and maintain our works, and which men, since the trying ordeals of earthquake and fire, have done almost superhuman work to, in a very short space of time, rehabilitate our water supply."

At Santa Barbara, V. E. Trace, Superintendent, Water Works Department, has stated:

* * * "The employees responded without call and were ready to render their assistance immediately following the disaster. At 10:45 a. m. (the earthquake shock occurred at 6:42 a. m.) the pressure was 75 pounds and at 12:00 noon was normal." * * * "Carl Wynant, Engineer and Superintendent of the Montecito County Water District, with his employees were on hand to render assistance and were certainly appreciated. The two sections of the East Transmission Main were replaced by them and the service of Reservoir No. 1 was resumed within forty-eight hours."

Details of Earthquake Damage. For those who may be interested in having further details of the earthquake effects in west central California on April 18, 1906, in Santa Barbara on June 29, 1925, and Long Beach and vicinity on March 10, 1933, the writer has prepared brief reviews which appear as an Appendix to this paper.

References. The following references will be found of value in studying earthquake effects upon water distribution systems and upon water works in general:

The Water Supply of San Francisco, California, Before, During and After the Earthquake of April 18, 1906, and the Subsequent Conflagration—dedicated to the Hydraulic Engineers of America—by Hermann Schussler, Chief Engineer of the Spring Valley Water Company, July 23, 1906, pp. 103.

The Effects of the San Francisco Earthquake of April 18, 1906, on Engineering Construction—Reports of a General Committee and of Six Special Committees of the San Francisco Association of Members of the American Society of Civil Engineers, Paper No. 1056, Transactions, American Society of Civil Engineers, Vol. LIX, December 1907, pp. 208-329.

Seismic Activity in Santa Barbara by V. E. Trace, Journal of the American Water Works Association, Vol. 15, No. 4, April, 1926, pp. 404-408.

Earthquake Effects on Water Supplies, Journal of the American Water Works Association, Vol. 26, No. 6, June, 1934.

Long Beach, by Fred S. Porter, pp. 769-775,

American States Water Service Company, by C. P. Harnish, pp. 775-778,

Lynnwood, by A. J. Bateman, pp. 779-780,

The Dominguez Water Company, by E. P. Tallon, pp. 780-784,

South Gate, by L. H. Rothkranz, pp. 784-787.

Some Effects of the San Francisco Earthquake on Water Works, Streets, Sewers, Car Tracks and Buildings, by Professor C. Derleth, Jr., Engineering News, Vol. LV, No. 20, May 17, 1906, pp. 548-553.

Ditto, No. 18, May 3, 1906; ditto, No. 26, June 28, 1906.

The Structural, Municipal and Sanitary Aspects of the Central California Catastrophe—IV—by Professor Charles Gilman Hyde, Engineering Record, Vol. LIII, No. 25, June 23, 1906.

Appendix

Earthquake Effects Upon California Water Distribution Systems In West Central California, April 18, 1906.

San Francisco

Statistics of Supply. On January 1, 1906, the distribution system of the Spring Valley Water Company embraced 11.5 miles of wrought-iron pipe ranging in diameter from 44 to 13 in., 334.1 miles of cast-iron pipe from 30 to 6 in. in diameter, and 96.0 miles of 4-in. and 3-in. cast-iron pipe, all totaling 441.6 miles.

The supply was received through the so-called Pilarcitos, San Andreas and Crystal Springs pipe lines delivering respectively to the Lake Honda, College Hill and University Mound distributing reservoirs within the City of San Francisco.

Within the City a natural lake, Lake Merced, could be drawn upon for a limited supply of water. The distribution system contained three pumping plants and 7 distributing reservoirs and tanks in addition to the three reservoirs above named. The total holding capacity of all 10 reservoirs was about 492 m.g.

The population of the City in 1906 was about 390,000 and the average daily water consumption approximately 35 m.g.

Earthquake Effects on Distribution System. The earthquake effects upon the supply conduits and distribution system of San Francisco can perhaps best be told by quoting from Mr. Schussler's Report, previously referred to:

"The earthquake of April 18th, 1906, followed by a general conflagration, destroyed the largest part of the business portion of San Francisco, as well as a considerable part of the adjacent residence district.

"The earthquake shock, which occurred about 5:15 a. m. on April 18th, although not injuring our main storage reservoirs in San Mateo County, nor our water sources in Alameda County, practically destroyed the upper thirty-inch conduit line, from Pilarcitos Reservoir, while it broke the lower 44-inch pipe line from Crystal Springs Reservoir for a total distance of about 2,850 feet, and seriously ruptured the 37-inch portion of the middle level San Andreas pipe line.

"Of the City Distributing Reservoirs, only Lake Honda Reservoir, of about thirty-three million gallons capacity and 365 feet elevation, was seriously injured by the earthquake; but, in spite of this fact, on the morning of April 21st, when the fire in San Francisco was practically under control, it still contained over one-sixth of its capacity.

"The most serious injury sustained by the works were the ruptures caused by the earthquake, in hundreds of places, in our city main pipe distributing system, especially where the streets crossed filled ground and, particularly, where such filled ground covered former deep swamps, which swamps, during the earthquake, subsided, tearing off sewers as well as water and gas pipes.

"Another as great and fully as fatal damage to the water distributing system was caused by the fact that the service pipes, supplying the many thousands of houses, hotels, factories, etc. (which the conflagration swept away with enormous rapidity, beginning immediately after the earthquake), were torn off, in and by the burning and falling buildings, allowing the water in the main pipe system to flow freely in tens of thousands of uncontrollable and inaccessible jets, large and small, into the accumulated debris of the burning building."

* * * *

"We also require heavier thickness of metal in the body of the pipe and a heavier and considerably deeper bell than is generally customary in American city water works. This increase in dimensions proved itself, during the earthquake, a very wise provision, as, in spite of the terrific twisting and wrenching that the city pipe system received all over the city, the breaks in the main pipes (considering our great length of distributing system of 441½ miles) were comparatively few, and these were, in the large majority of cases, principally confined to and caused by the sudden sinking of the streets over the old swamps, which movement (the same as happened to the city's sewers there) tore the pipe over the swamp away from the pipe on terra firma.

"In the streets within the main body of the sunken swamp districts, which, during the earthquake, rapidly moved up and down and sideways, back and forward, like jelly in a shaken bowl, there were also, naturally, a number of breaks in the street pipes, caused by the twisting and rapidly undulating motion of ground in which the pipes had to be laid.

"Furthermore, we had a number of breaks in the main pipes in such streets that were constructed over loosely and poorly filled depressions.

"The works of our company in the country (except where they were un-

avoidably torn up and destroyed by the earthquake faults crossing and recrossing the same) and in the city (where the main pipes, wherever crossing swamps and fills were broken) have withstood the terrific strain to which they were submitted in a most remarkable degree."

* * * *

"All the three large pumping plants in San Francisco, viz: Black Point, Lake Merced and Seventeenth Street Station, were not injured by the earthquake, as well as the ones at Millbrae and Crystal Springs. At Belmont Pumping Station the only slight damage done was the breaking of a flange on a steam valve on one of the five pumps, which has since been repaired; the other four independent plants there received no injury whatever.

"Lake Honda Reservoir, in San Francisco County, which was constructed by Engineer Von Schmidt and, later, added to by an architect named Jordan, was turned over to me in 1866. It was injured by the earthquake cracking the heavy western wall, the shock coming from the west and shaking up a sandy mountain, about 100 feet high, causing the slope to slide down towards the wall. By the free use of pure cement grout the large cracks and fissures in the west wall were successfully filled and closed, and the reservoir, having since been full, appears to be practically tight.

"Lombard Street Reservoir and Clay Street Tank, both in San Francisco, had their wooden roofs burnt off. The former has been cleaned and the brick bottom and sides, where necessary, covered with a new asphaltum coating; and the latter tank, after having been cleaned and painted, will soon be in commission again.

"All the other city distributing reservoirs were uninjured, both by earthquake and fire.

"The city pipe distributing system was broken and in many instances torn and twisted off, especially in places where the ground, over which the streets had been constructed, had been poorly and loosely filled over old deep swamps and soft marshes. There were also a number of breaks in the streets that passed with deep loose fills over former ravines.

"In solid ground there was very little trouble and but very few breaks. A number of the breaks on solid ground were caused by the use of dynamite and other explosives, employed in blowing down buildings.

"In the above sunken streets the city sewers, as well as other conduits, such as gas pipes, electric light conduits, etc., suffered the same as the water pipes, in that they were also similarly ruptured by the sinking and violent oscillations of the ground.

"On July 18th there had been discovered and repaired 300 breaks in the street pipe system, of which number 276 were in and immediately adjoining the burnt district, while in the entire balance of the city, viz., in the unburnt district, only 24 breaks have been found and repaired.

"But the most serious problem that we have had to meet in rehabilitating the city distributing system has been the work of shutting off the thousands of broken service pipes and house supply pipes that were torn off by the burning and falling buildings during the conflagration at the average rate of between about

6,000 and 7,000 service pipes a day, ranging from ⅝ of an inch to 4 inches in diameter and sometimes over, which service pipes were thus torn off and left running wide open during the entire conflagration, discharging uselessly into the accumulated debris.

"The total number of the house, hotel, elevator, standpipe and factory connections and of automatic-sprinkler pipes, thus torn off and left open by and during the entire conflagration, amount to over 23,200 separate pipes in the burnt district. The breaking, tearing and twisting off of the main street pipes in over three hundred places and the opening of these many thousands of service pipes left but little pressure in the main pipes in the unburnt district and for the Fire Department along the burning margin of the same."

* * * *

"One of the most serious breaks in the main pipe lines was caused by the earthquake shaking and settling down, by from one to five feet, the region between Eighteenth and Nineteenth streets, on Valencia street. Here an old swamp had been loosely filled in, many years ago, by any and all kinds of material and rubbish obtainable, the fill being twenty feet or more in depth. Our pipes, which had to be below the pavement of the street, had to cross this region. Being aware of this state of affairs regarding the character of the foundation and fill (I constructed the pipe in 1876), I remembered the location of this swamp, and made our 22-inch pipe of wrought-iron. I put in a number of cast-iron bell joints, with lead joints, which would give or yield somewhat in case of a slight settlement. This pipe is to-day in a perfect condition, except at the points where the swamp dropped down suddenly, during the earthquake, from four to five feet, which naturally tore off the pipe both at the north and south boundary of the swamp. This serious break was quickly repaired by laying across the swamp and over the top of the pavement and well into terra firma on each side of the sink, a long stretch of 24-inch cast-iron pipe. This gave us a chance to drive a supply of water along Market to Sansome street, to Montgomery avenue, etc., to and into the Francisco Street Reservoir."

Effects on Service. Again quoting from Mr. Schussler's Report one may obtain a picture of the restitution of service following the earthquake and fire in San Francisco.

"The main conduit lines, connecting the large county storage reservoirs with the city distributing reservoirs, were rapidly repaired, the upper level conduit delivering from Lake Merced, within sixteen hours after the earthquake, seven million gallons a day into town, and the middle level, or San Andreas conduit, within sixty-two hours after the earthquake, delivering eight million gallons a day into the city.

"The water storage on hand in the city reservoirs, at the time of and for several days after the earthquake, coupled with the fresh supplies thus brought in from the outside, enabled us to send water through the unburnt district of the Western Addition towards and to the burning district during the entire duration of the conflagration."

* * * *

"Before noon of April 18, all orders for materials, tools, fittings and men were given for the immediate repair of the 37-inch San Andreas pipe at Baden, and also for the reconstruction, in as short a space as possible, of the badly ruptured 44-inch Crystal Springs pipe and bridge.

* * * *

"On the morning of April 20, the water from San Andreas Reservoir was then slowly and carefully turned again into this long line of wrought-iron pipe.

"By 7 o'clock on the evening of April 20, or sixty-two hours after the earthquake, a second stream of water was pouring into its respective city reservoir, the College Hill Reservoir. This reservoir had been emptied of its contents of 11,400,000 gallons, which it contained, at 7 a.m. April 18, by its main arterial pipe, 22-inch diameter, and its companion pipe, 16-inch diameter, both on Valencia street, having both been torn off and destroyed between Eighteenth and Nineteenth streets by the sinking of Valencia street of from one to five feet.

"This new supply, thus brought into the empty reservoir on Friday evening, while portions of San Francisco were still burning, was very welcome to a large portion of the unburnt South Mission and to the larger part of the Potrero, and to the large factories there. This additional volume of water, thus brought into and through College Hill Reservoir (at 255 feet elevation) was gradually increased to 8,000,000 gallons a day, which, with the supply of from six to seven million gallons daily sent in from the Lake Merced Pumping Station, made a total supply of from fourteen to fifteen million gallons daily flowing into the city."

* * * *

Response of Personnel. That the successful restitution of service in an interval which was extraordinarily brief, considering the scope of the disaster wrought by both earthquake and fire in San Francisco was due to trained, efficient and loyal personnel, is reflected in the following comments by Mr. Schussler:

"Immediately after the earthquake occurred, at about 5:15 a.m., April 18th, finding that the telephone service had been interrupted by the earthquake, I started for the Spring Valley Water Company's pipe yard at Bryant street, between Fourth and Fifth streets. I met the head foreman, Mr. Gleeson, with his buggy, who was coming after me, and we found considerable difficulty, owing to the widespread conflagration south of Market street, to get to the pipe yard, where pipes, stores, repair pieces, horses, wagons and men are kept.

"Many of the company's men had reported there and were on hand to carry out any orders. The men were at once organized in squads and, under the direction of the several foremen, started out to discover the extent of the damage done by the earthquake to the main street pipe system and, wherever possible, to repair breaks, but, in such manner, as not to interrupt the flow of the water from the respective city distributing reservoirs towards and to the burning districts.

"As the telephone service between the city office and country reservoirs had also been interrupted by the earthquake, I started out at once to examine where

and to what extent these main country conduit lines were ruptured. On the road I met my assistant, Mr. Lawrence, coming towards town to report to me what the various pipe walkers (one for each line) had reported to him."

* * * *

"In spite of the above-described condition of the streets, our various squads of repair forces, working under a systematic and methodically devised plan of rehabilitation, have so far succeeded in putting nearly 75 per cent of our distributing system in the burnt district into normal condition."

* * * *

"In selecting the men to fill either or all of these positions, I have always placed the 'good character' of the men as the first and foremost requirement. After that came energy, adaptability and skill.

"Thus I soon found out for what specialty a man was best fitted. If, thereafter, he fully came up to my expectations, he was regularly employed at fair pay and, when his qualifications permitted and the opportunity offered itself, he was advanced in position and salary."

* * * *

"Having steadily followed this method, for fully four decades, of carefully selecting, thoroughly training and properly treating our employees in the Engineering, Construction and Maintenance Departments, I can say, from the bottom of my heart, that the splendid physical condition of our very extensive works, even after the earthquake (which works show an endless variety of constructions best adapted to the climatic, physical and local circumstances), is largely due to the faithful work of every man that has helped me to construct and maintain our works, and which men, since the trying ordeals of earthquake and fire, have done almost superhuman work to, in a very short space of time, rehabilitate our water supply."

* * * *

The East Bay Cities—Alameda, Berkeley, Oakland, Piedmont—Supplied By The Contra Costa Water Company.

General Statement. The destruction caused by the earthquake of April 18, 1906, in the cities of Alameda, Berkeley, Oakland, and Piedmont, and in adjoining areas, served by the Contra Costa Water Company, was not heavy. Breaks in pipe lines invariably occurred in soft ground, or where pipes passed from soft yielding materials to those which were firmer. Only three important breaks occurred on main supply pipe lines. None of the pumping plants were affected and all of the distributing reservoirs were intact. The distribution system in west Oakland, on filled ground, was damaged to the extent that some of the smaller pipes and some service connections were broken. The earthquake shock in this region was severe, but certainly not as vio-

lent as that on the San Francisco peninsula. The experience in the East Bay Cities would seem to warrant the conclusion, as in San Francisco, that well constructed water supply systems on good foundations in firm materials will be durable and permanent as related to earthquake effects.

Santa Rosa.

General Statement. The earthquake shock on April 18, 1906, in Santa Rosa, Sonoma County, California, a town of some 7,000 inhabitants, was sufficiently violent to destroy almost without exception the brick buildings in the business district. This section was burned because many fires started simultaneously in the rubbish and the fire fighting equipment was unable to cope with the situation.

However, no breaks occurred in the water distribution system with the exception of a few service pipes which were broken at the building lines. No sewers were damaged. There was no unequal settlement. The artesian sources of supply did not suffer and the pumping plants were not injured. There was no lack of water. As a matter of fact an above-normal supply of water with increased pressure was available because of reduced demands.

San Jose

General Statement. The destruction of buildings wrought by the earthquake of April 18, 1906, in San Jose, with a population of about 25,000, was appalling. Fortunately, the city was spared a conflagration.

Neither the water supply system nor the sewers were materially damaged. The building damage was due to poor construction unable to resist the vibration effects. There seemed to be no unequal ground settlement.

Santa Barbara, June 29, 1925.

The Earthquake. The earthquake which caused great damage to buildings in Santa Barbara, California, occurred at 6:42 a. m. on June 29, 1925. The main shock is reported to have lasted for 19 seconds. Its effects appear to have been highly localized. The population of the city was then about 26,000.

Statistics of Supply. The main supply of water was obtained from Gibraltar Reservoir on Santa Ynez River by gravity through a

tunnel 19,800 ft. in length piercing the mountain range to the east of the city. A considerable amount of infiltration was derived from that tunnel and this supply was augmented for a period due to the earthquake. The system also contained an infiltration gallery known as Cold Springs Tunnel. A small stream, Mission Creek, supplied an impounding-distributing reservoir designated Sheffield Reservoir. There were three additional service reservoirs. The daily water consumption ranged between about 2.5 and 8.0 m.g.

Earthquake Effects on Distribution System. Considering the severity of the earthquake which destroyed many buildings, the damage to the distribution system was slight and not to be compared with the injury to structures. In a section of the city on or near the fault line, where the ground was most severely shaken, one cement joint was fractured and one service sheared off. Elsewhere several leaks occurred in lead joints, some cement joints were fractured, and some services were sheared off at the corporation cocks. Only one cast-iron pipe was actually broken by the earth movement itself. The first break observed was that of a 12-in. Class B cast-iron pipe caused by the falling of a parapet wall of a three-story building. This wall fell into the street directly above the pipe and was reported to have driven a section of the pavement 3.5 ft. into the ground.

No injury to three of the distributing reservoirs was reported. The dam forming the fourth reservoir, known as Sheffield Reservoir, was a puddled earth fill, 25 ft. high and 800 ft. long, without a drainage system. When the heavy shock occurred, the dam opened near its south end and about 500 ft. in the center slid out in the form of a hinge.

At the pumping station a 10-in. standard screwed discharge main from the pumps to the distribution system was torn apart at the joints. The caisson, 30 ft. deep and 25 ft. in diameter, was fractured causing the pumping pit to become flooded with water. The brick walls of the boiler room housing were demolished.

Effects on Service. The Superintendent of the Water Works Department, V. E. Trace, reported that the damage caused to two of the main trunk lines "drained the system and within ten minutes the water pressure registered 5 pounds (dropping from a normal of about 140 pounds per square inch), and within less than thirty minutes thereafter, through the quick action of the Water Department em-

ployees in closing the damaged sections of the system, the pressure in the system was restored and it is with gratitude I wish to state that the employees responded without call and were ready to render assistance immediately following the disaster. At 10:45 a. m. the pressure was 75 pounds and at 12:00 noon was normal".

Long Beach and Vicinity, March 10, 1933.

The Earthquake. The first severe shock, which caused the major amount of damage, occurred at 5:55 p. m., March 10, 1933, and affected a large area in and around the City of Long Beach, California. There were many subsequent shocks, but none so violent or disastrous as the first.

Long Beach.

Statistics of Supply. This city of approximately 150,000 inhabitants was supplied by 32 wells from 10 to 16 in. in diameter and ranging in depth from 200 to 1668 ft. Twenty-one wells were of 26-in. diameter down to a depth of 250 ft. Twenty-five wells were equipped with deep-well turbine pumps and seven were pumped with air. There were two booster stations. The distributing reservoir, located on elevated ground, consisted of 6 steel tanks, each 132 ft. in diameter and 35 ft. deep, with a total holding capacity of 20.7 m.g.

The collection, transmission and distribution pipe system embraced 402.4 miles of pipe, said to have been serving about 150,000 persons through 28,052 services, 10,454 of which were of cast-iron and the remainder, variously, of lead, steel, wrought iron and copper. The system was 100 per cent metered. In the collection pipe system were 6.8 miles of concrete pipe. In the transmission and distribution system there were 373.8 miles of cast-iron pipe and 21.8 miles of steel pipe.

The average daily water consumption was approximately 18 m.g. or 128 gal. per capita.

Earthquake Effects on Works. No damage was suffered by the pumping or electrical equipment at any of the wells or to the pipe connections, but at some well locations the earth movement was so great that the oil was thrown out of the tanks of the oil switches. The heavy transformers were shifted on their foundations at all of the wells and cracks developed in the concrete floors of the pump houses. No damage was done to the booster pumping station founda-

tions, the pumps, electrical switches or pipe connections. However, the power line to one booster station was severed and one station wall fell, injuring the bus bars.

The only damage to the steel tanks comprising the distributing reservoir was a small settlement of a portion of one of the six tanks, and slight injury to the roofs.

The concrete collecting pipe system was broken or sheared in a few places and a 30-in. valve in the line was broken by compressive action.

In the distributing pipe system there were 130 breaks in 367.5 miles of cast-iron pipe ranging in size from 30 in. to 2 in. There was only one break in 30.1 miles of cast-iron pipe 12 in. in diameter and over, where one joint was pulled in a total length of 18.4 miles of 20-in. pipe. Of the 130 breaks, 52 per cent occurred in dredged fill on tide flats, 38 per cent in natural silt where the ground water level was close to the surface, and 10 per cent in hard adobe soil.

In the 21.8 miles of steel pipe varying in size from 16 to 2 in., there were 135 breaks. All of these occurred in one district in which the pipe had already reached a condition where replacement was necessary.

Of the 10,454 cast-iron services, only two breaks occurred between the main and the tee at the curb. All other breaks were either those of brass nipples or of malleable fittings at the curb tees. Altogether there were 85 breaks in the 28,052 services. Seventy-five per cent of these were in the dredged fill tide flats.

Due to the shifting of houses and other structures on their foundations there were probably hundreds of breaks in private services between the meters and the structures.

Effects on Service. Two groups of wells and the main booster pumping stations were provided with two independent sources of power. All power circuits were shut off immediately following the first severe shock and were not again turned on for from 19 to 90 minutes thereafter. Within an hour and a half after the shock 7 wells, with a combined capacity of 7,000 g.p.m. (10 m.g.d.), were pumping directly into the distribution system.

The draft due to main line and service pipe breaks, and to unusual demands for fire fighting, emptied five of the tanks in the first six hours after the earthquake and left only 8 feet of water in the

sixth. By this time the resumption of pumping at the main booster plants prevented further depletion. All six tanks were completely filled in 36 hours after the earthquake.

American States Water Service Company.

Statistics of Supply. This company supplied water to some 42,000 consumers in 30 communities in Southern California. About half of the population served was resident within the area affected by the earthquake. In this area the company had 14 water works systems, the largest serving 6000 persons and the smallest only 70. The supply was derived entirely from wells, 35 in number. The combined distribution systems contained 365 miles of pipe, of which about 25 per cent was cast-iron and the remainder steel. A considerable proportion of the latter was riveted pipe with slip joints. Altogether, in the affected area, the company had 7 elevated steel tanks, all of standard hemispherical bottom type on steel towers approximately 100 ft. high.

Earthquake Effects on Works. No damage was suffered by any of the 35 wells and no concrete receiving cisterns or reservoirs were injured to any appreciable extent. Moreover, none of the company's pumping plants was damaged either as respects structures or equipment.

All of the 7 elevated tanks were injured. In 4 cases the damage was confined to the diagonal tie rods in the top panels. These rods had stretched and loosened. In one case there were several easily repaired leaks in the hemispherical bottom, in addition to tie rod damage. In another case a tie rod had broken and others were so stretched that they required removal and shortening. In the seventh case the riser pipe broke and emptied the tank, else it would surely have collapsed due to the breaking and excessive stretching of the tie rods themselves and to the bending of the connections between two of the columns and the tank. This particular locality was severely shaken.

Chargeable to the earthquake there were 247 leaks in the 365 miles of distribution pipe. However, and this fact is of great significance, only 4 leaks occurred in the approximately 90 miles of cast-iron pipe. All of the other leaks were found in steel pipes of small size.

The leaks in the steel mains were of many sorts. The minor

ones were due to rust spots or pits which, sooner or later, would have caused leaks anyhow. In riveted steel lines there were numerous split longitudinal seams as well as sheared rivets. A number of leaks occurred in service connections which were made up of steel pipe without flexible goosenecks at the mains.

Effects on Service. In the larger systems water service was adequately maintained at all times. Sufficient elevated storage, power service from two different sources and some gas engine reserve units, were important factors contributing to the maintenance of service. In one community with 175 consumers the service was interrupted for some 12 hours or more. Because of power failure a group of 70 consumers was without water for 6 hours. In another small community, 25 per cent of the distribution system required to be cut out of service for 18 hours due to pipe line breaks. Thus about 300 of the 21,000 consumers in 14 separate water works systems supplied by the company in the district affected by the earthquake were without water for short periods immediately following the first severe shock.

Lynnwood

Statistics of Supply. This city of approximately 8,500 inhabitants was supplied by 5 wells ranging in depth from 152 to 436 ft. The water was pumped directly to the mains and to three small elevated tanks. In 1932 there were 2100 services, of which 3.5 per cent were metered. The daily consumption ranged from 0.5 to 2.3 m.g.

The distribution system comprised 45 miles of mains, 30 per cent being of cast-iron, 15 per cent of wire-wound wood stave pipe, and the remaining 55 per cent of light gage riveted steel pipe 20 years old.

Earthquake Effects on Works. The wells and pumping equipment suffered no damage. In the 14 miles of cast-iron pipe only two small leaks occurred, apparently due to faulty caulking when the lines were laid. Altogether some 150 breaks or leaks required repair in the wood stave and riveted steel pipe lines. One elevated tank of 25,000 gal. capacity collapsed and a 7,000-gal. elevated tank was put out of plumb due to the breaking of all of the tie rods in all three panels.

Effect on Service. Except for a brief interval when the electrical power was shut off, water service was not interrupted. In some areas, due to large breaks, the pressure fell to 12 lb. per sq. in. and "had fire

occurred in these sections serious consequences might have followed" —A. J. Bateman. All of the larger breaks were repaired in three days and all of the other leaks in about three weeks.

Dominguez Water Company.

Statistics of Supply. The works of the Dominguez Water Company supplied about 10,000 persons scattered over an area of 20 square miles. The supply was derived from 12 wells, 11 of which were within a radius of one-half mile of the main pumping station. Five of the wells were pumped by air and six by motor driven deep well turbines. The company also operated a remote independent station supplied by one well with a motor driven deep well pumping unit. The main pumping station contained both stream and electrically driven equipment. There were two distributing reservoirs of the earth embankment type.

The distribution system consisted of 75 miles of pipe, 22 miles of which were of wire-wound redwood stave pipe and the remainder of riveted steel pipe. Prior to the earthquake most of the steel pipe had been surrounded with concrete. The surface materials were deep deposits of sand and quicksand, water saturated.

Earthquake Effects on Works. The earthquake developed the fact that the main pumping station was located directly over the Inglewood fault. The structure was virtually demolished. The main steam lines were torn apart and debris covered all of the equipment. The building was of unreinforced concrete.

None of the wells was damaged and no injury was suffered by the 22 miles of wood stave pipe. Only 7 breaks occurred in the riveted steel pipe lines which had been coated with concrete. Five of the 7 breaks occurred within a distance of 150 ft., and of these only two were serious. The locality of these breaks was apparently one in which the shock was exceedingly severe.

Effects on Service. Water service to 90 per cent of the consumers was practically uninterrupted. The motor driven units in the main pumping station were not seriously injured and were quickly put back into service. On May 9, in two months lacking a day, the steam pumping service was restored. All pipe line breaks were repaired within 48 hours.

Following the shock the pressure dropped rapidly in the distri-

bution system until the main valves at the reservoir, on the lines from the pumping station thereto, were closed.

South Gate.

Statistics of Supply. The South Gate water works supplied a population of 21,500 persons resident in an area embracing 7 square miles. The supply was derived from 8 wells, 600 to 1000 ft. in depth, equipped with deep well turbine pumping units. There were two 150,000-gal. elevated steel tanks whose tops were 150 and 165 ft., respectively, above the ground surface. The normal water pressure was between 55 and 60 lb. per sq. in. The pumping was direct from wells to mains and tanks. All services were metered and the consumption ranged from about 500,000 to 1,500,000 g.p.d.

In the distribution system the mains varied from 16 to 4 in. in size and consisted of 150 miles of cast-iron pipe conforming to A. W. W. A. specifications, 12.7 miles of wire-wound wood stave pipe and unstated amounts of precaulked cast-iron pipe and steel pipe.

Earthquake Effects on Works. None of the wells and their equipment was reported to have been damaged with the exception of one 12-in. well in a deep pit located in close proximity to one of the elevated steel tanks which collapsed. The well in question was 680 ft. deep in a circular pit 6 feet in diameter and 26 feet deep with a 6-in. concrete wall. The well casing had been extended to the surface and the pit filled with sand. Examination subsequent to the earthquake showed that the well had been offset about four inches at and below the floor of the pit.

The collapse of one of the elevated tanks was apparently brought about by the settling of one of the piers and the breaking or stretching of the tie rods. The failure of this tank washed out 50 ft. of curb in the nearby street and carried a garage, located 50 ft. from the tank, through a distance of 30 ft. without injury to a sedan automobile inside other than to the hubcaps on one side.

The second elevated steel tank was left some 12 to 18 in. out of plumb. The tie rods were badly stretched and the turn-buckles and eye-stubs had partly broken loose from the rods in 12 places.

In the 150 miles of cast-iron pipe conforming to A. W. W. A. standards, with Portland cement joints, there was but one bell break.

This was caused by a sharp upheaval of the ground which raised the curbs, sidewalks and paving of the street.

In the 12.7 miles of wood stave pipe there were 20 breaks, all caused by the breakage of the wrapping wires through corrosion and vibration. However, no bad leaks were found even in places where the ground was badly cracked and where "the lines must have moved about like a rubber hose."

There were many leaks in the cast-iron mains laid with pre-caulked joints due to the pulling of spigot ends out of bells.

There was no injury to the approximately 3500 service connections between the mains and the curbs. All of these services consisted of ¾-in. and 1-in. annealed copper tubing.

Effect on Service. At no time subsequent to the earthquake did the pressure fall below 25 lb. per sq. in. except for ten minutes following the collapse of the 150,000-gal. elevated steel tank.

"On the day following the earthquake and for about three weeks afterwards, the Los Angeles County Health Department made tests of samples taken from each of our wells and from house taps and hydrants throughout the system, without finding a single case of contamination in our city water."—L. M. Rothkranz.

PROTECTION OF PUBLIC WATER SUPPLIES—A SYMPOSIUM

ABSTRACT BY E. SHERMAN CHASE*

[*January 15, 1942.*]

ROGER W. ESTEY.† One of the questions that has arisen concerns the protection around pumping stations, reservoirs, standpipes and other water works structures. A lot of smaller towns and cities that are in defense manufacturing areas have that problem confronting them. The superintendent of a little town who contacted me said that he had a pumping station and two standpipes and that if it were necessary to place guards at these standpipes or the station for twenty-four hours a day, he would need many more men than he has now. It is different in some of the larger cities like Lynn, because there's so much at stake. There has been talk about erecting fences around pumping stations and also having the grounds illuminated. Some feel that it is better to leave the station in darkness because if the grounds are lighted they attract attention. Now, would it be better to illuminate or have it so that you could illuminate if you needed to; or is it best to have a fence and armed guards? A fence will keep some people away but some will get over it. What is the best thing to do around filtration plants? In other words, what is the thing to do with respect to the physical guarding of water works properties at the present time?

RALPH E. TARBETT.‡ It seems to me that we should consider what value it would be to enemy agents to attempt the destruction or interruption of a water supply. If we have a small supply that has no defense value, the protection could be much less in comparison with another supply that was very important to defense efforts. Certainly there isn't any reason for putting on expensive protection unless there is enough income to pay for it.

Fencing, lighting, and guarding are recommended around key structures. Perhaps what is more important is a little better knowl-

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edge of the employees, the control over visitors or even over employees in parts of the plant where they should not be so far as their work is concerned. It is also a question of better guarding the records and plans in the main office.

We have hoped to make a survey of all the essential and important water plants to determine what protective measures have been put in force, and to have those measures reviewed by a group that has been making a study of this protection program. With such a review, recommendations can be made to particular utilities relative to protection of weak points. We hope to start that work before very long.

On the question of lighting and blackouts, I think that comes down to guarding during a blackout. If guards do not allow anybody in or out of a plant during a blackout and no one is permitted around the grounds, you probably have just the protection you need. Lighting, so that the guards may see, is important.

I don't think we can ever get perfect protection and we have to use a little reasoning to determine how extensive protective measures should be. We don't want to pay more for protection than the plant is worth. The degree of protection should be worked out from that angle.

ARTHUR D. WESTON.* I might say that that question has bothered all of us. We are convinced that there is practically nothing we can do to safeguard water works systems from aerial bombardment. Guards are not an assurance in that regard. It comes down to what protection you should give your property against sabotage. We have interpreted the instructions from the Surgeon General in this way—that there is no danger of sabotage to any plant which is of no vital importance to the defense program. It is obvious that residential towns need not be protected. The Massachusetts Department of Public Health is recommending that any water supply that is used in any way in connection with the national defense program should be protected. Gravity surface supplies should be protected at the gatehouse and at the purification plant with some attention being given to main pipe crossings over bridges or across rivers, sections of such pipes often being exposed. Pumped surface water supplies should be protected at the pumping station, purification plant and distributing reservoir.

*Water Coördinator for Massachusetts and Chief Engineer, Massachusetts Department of Public Health.

In connection with chlorination, we have recommended that all surface water supplies must be chlorinated if they are used in connection with national defense. It is my opinion that they should be chlorinated whether they are used in defense or not. In the case of ground water supplies, any ground water supply used in connection with national defense, if it is exposed to pollution, should be chlorinated. If you have an open dug well or caisson wells, they certainly are exposed to pollution and ought to be chlorinated.

We have had no sympathy with the excuses of some of the larger municipalities for not taking precautions. We had a letter from one municipality that read something like this: "We cannot attempt to chlorinate our water supply at the present time because we have not sufficient funds." This city has one of our largest surface water supplies in Massachusetts and it is not chlorinated. A large proportion of the receipts of that water department are diverted for purposes other than water supply. We are going the limit with cases like that and see that the supply is chlorinated.

MR. CHASE. With reference to the possibility of direct hits from bombs in case of an aerial attack, it is of interest that so far, as has been reported by Mr. Binger of New York who has been in England recently, there has been no direct hit on a pumping station in England.

HORACE J. COOK.† About a year ago when it was apparent that active warfare was only a question of time, the Maine Water Utilities Association began its preparedness program. A school of water works defense was inaugurated. This was financed by the Federal government with the University of Maine as sponsor. It was in direct charge of Stephen Taylor, former President of the New England Water Works Association.

Our first speaker was E. Sherman Chase, who is conducting this meeting. Among the other experts who spoke were George E. Russell, Samuel M. Ellsworth, Gordon M. Fair, Robert Spurr Weston, and several others of equal prominence. These classes were held in five different localities on different evenings, so that each speaker spent about a week in the state. The superintendents, and many of the officials and employees attended. At the conclusion of the course each one who had been present at these classes received a certificate

†Superintendent, Auburn Water District, Auburn, Maine.

from the University of Maine, stating that the holder had completed the course in "Defense Training for Water Works Operators." The entire course of lectures has been printed by the Maine Water Utilities Association, and can be procured from the Editor, S. S. Anthony, Augusta, Maine.

As soon as this program was completed, a clearing house committee was appointed. Questionnaires were sent to every water utility in the state. These asked for the names of the officials, addresses, and telephone numbers; the miles of each size of pipe in the system, the inventories of all pipes, gates, hydrants, and specials from 4 in. up, amount of jointing materials, a list of all equipment, a list of emergency chlorinators with chemicals on hand, and number of men available.

The state was divided into zones. From the length of miles of mains in each zone, the amount of material that should be on hand in each zone was computed. Letters were then sent to communities that were lacking in any materials suggesting that purchases be made to remedy this. Large cards suitable to be hung on the wall were sent to each superintendent. On these were printed the telephone numbers of the clearing house officials at the central office at Augusta; also the names, addresses, and telephone numbers of the officials of the other water companies in that zone.

In case of trouble, the plan is to call the central office at Augusta where information locating the desired material in that zone will be given. The superintendent in trouble telephones there, and to save time, the material is delivered by the community of which help has been asked. The number of men in each town available for use in other areas has been listed, together with their qualifications.

Every superintendent is to have a printed list of the men available in his section of the state. Then, in case of trouble, he can telephone direct to the utility which has the type of man to spare and say "Send him along."

In most of the communities, the plumbers have been enlisted to work with the water repair crew in case of trouble. They are being well organized, and in several places classes are being held to show the plumbers the use of jointing compounds, repair sleeves, tapping mains for service connections, etc.

The greater part of the water utilities in the state have erected

guard fences, and installed flood lighting systems. At vulnerable points men are on duty all the time.

HOWARD H. POTTER.* I certainly appreciate the work which the Maine Water Utilities Association has done. Long before a State Coördinator was appointed, our Association had done the primary work that the Coördinator would have had to do, and accordingly I have been relieved of that work. I think it is safe to assume that the clearing house committee of that association and the state water coördinator will work in the closest coöperation. I hope that they can feel that they will get the help they want from me. As the coördinator for Maine, I have adopted the policies of the other New England Coördinators.

CHARLES D. HOWARD.† A few days ago a five page circular letter embodying information and recommendations was sent out to water superintendents. Thus far there has been no notable reaction to this. The great majority of our supplies have no substantial defense importance, although there are a certain number involving some defense manufacturing. Our people are inclined to be pretty optimistic as to the probability of any attack or sabotage. So that when it comes to guarding our supplies, it thus far has been difficult to arouse much enthusiasm. The tendency is to claim that it is not feasible to do this and that the cost would be too great. We have a ruling that neither the Army, the State Police, nor the State Guard can participate in that sort of thing, hence what is done must be done at the expense of the municipality or of the water company concerned. Thus far, only two cities—Manchester and Rochester—have a real guarding system so far as I have yet learned. Portsmouth, also I should have mentioned, but there, I believe, there is some coöperation with the Army because of the exceptional military importance of that area. A few other places do have attendants at pumping stations and gatehouses at night. For the most part, but little actual guarding is being done, but we expect to be able to bring about developments in this situation in the near future.

My letter of recommendations also had something to say about restriction of boating and fishing on our larger reservoirs and smaller ponds and lakes. There is a provision of law which permits water

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†Water Coördinator of New Hampshire and Director Division of Chemistry and Sanitation, State Board of Health, Concord, N. H.

works officials to regulate such activities, and my recommendation was that these be either prohibited or at least sharply restricted. Manchester has already prohibited boating and fishing on its Massabesic Lake supply. Concord has a system of permits for boating on its Penacook Lake source. Ice fishing should be similarly restricted by use of a permit system. In the case of our town supplies, ice fishing is prohibited under a special state act.

In this matter of securing chlorination, it is a rather difficult proposition. However, our department was a pioneer in this activity and a comparatively large share of our supplies are now so treated. Our department is empowered by law to order any improvement of a water supply, but it is necessary first to have a hearing and to show due cause for issuance of such an order. We held a hearing just yesterday that was rather typical on a matter involving a proposed order to require chlorination of the supply of a good sized resort town. As usual, the two objections were brought up, the financial aspect, as involved by the cost of treatment, the other, the apprehension that there would be an odor or taste in the water. It is very difficult to convince people that chlorination does not necessarily affect the flavor of the water. Consumers protest to us that they do not want their nice fresh water supplies injured by introduction of chemicals. We have to assure them that if chlorination is conducted in a proper manner there will be no odor or taste, and no quality impairment. We had another hearing two or three days ago involving a water company, and in that case the objection was altogether along financial lines, and their argument was that if such an order was to be issued, they would not be able to comply with it and would be obliged to liquidate.

What is particularly disturbing to me at this time is the request that chlorination now be carried out to the point of having a residual in the distribution systems.* With very low pH's as a rule and very little alkalinity, I don't see how carrying out the so-called breakpoint chlorination is going to be feasible with us, especially so without radical changes and additions to present equipment.

On the matter of inventories, these are being collected. Forms were sent out several months ago, and at this time a majority of them have been returned. When returns are completed, the data will be

*As recently recommended by the Surgeon General, U. S. Public Health Service.

tabulated. Concerning chlorinators, the great majority of those in our state are of the "hypo" type, using sodium hypochlorite solution. We have a great many of them, not only on our public water systems, but also on the water supplies of such places as tourist camps, juvenile camps, swimming pools, and hotels. For this reason, I am glad to learn of the probability that hypochlorites will continue to be available.

PERCY R. SANDERS.† We allow boating and fishing in New Hampshire on ponds over ten acres, under permits, with the restriction that they keep away a certain distance from the intake. What Mr. Tarbett has said to us about water works that are not in defense areas is most reassuring to us all, because there has been the problem of what to do and also what not to do. Our board talked this over at the start of this war; whether it was best to guard or not to guard, and they took the attitude that they were not going to get hysterical; we did not have any defense industries and we could not see any need of guards. The board did authorize me to have men employed twenty-four hours a day at our stations, to have flood lights put around and to have a double barreled shotgun handy.

The matter of chlorination is one of the most vital and important ones that we have to deal with, and as Mr. Howard says, we have to be careful about tastes and odors in our water supplies, but on the other hand, we've got to see that they are chlorinated. The matter of having emergency equipment on hand is important, and where we have chlorinators we should see that we have duplicate parts for every possible thing that we can need in that chlorinator. It may not be possible to get the duplicate chlorinator, but I think we can all get our duplicate parts. We are, as in Maine, having an inventory made of all the materials around the state and those returns have come in very well.

EDWARD L. TRACY.‡ The procedure has been about the same in Vermont as in other states. The instructions of Dr. Parran* together with the recommendations of the State Public Health Department as to how those could best be carried out, were sent to every town in the state. A year ago this month, the Public Health Department started warning the vital areas about the protection of their water sup-

†Superintendent, Concord Water Works, Concord, N. H.
‡Water Coördinator of Vermont and Sanitary Engineer, State Department of Health, Burlington, Vt.
*Surgeon General, U. S. Public Health Service.

plies and continued to issue warnings throughout the past summer. Results have been very good in some places. The largest city in the state has a perfect guarding system. You absolutely cannot get into any part of the water supply system. This is enforced by full-time employees and by gate sentries. The second largest city in the state, which has a water shed over a large area, is guarding the reservoir area and the chlorine house. Guards are deputy sheriffs which makes them employees of the State Department of Justice, so that there is no question of their authority. Some of the other places have made preparations for guarding or for partial guarding.

What to our mind is the most vital section in the state is that in which the machine tool industry is located. I was in two towns in that section yesterday and their water supplies are not fully guarded and a question was raised which is hard to answer. If I go in there and try to tell them to provide guards—and they don't dispute the fact that their water supply is the most vital utility in their town—they'll agree with me and agree that their plant should be guarded. But since water is the most vital utility, they raise the question, "Why is the Regular Army guarding bridges and power dams and not water works?"

The entire business of promoting the safeguarding of water supplies will be handled through the Division of Sanitation of the State Public Health Department. The Governor of Vermont, when appointing the State Water Coördinator made that person a member of the State Safety Council, which does away with any question of authority. The last special legislature gave the State Council of Safety some unusual powers in the event of an emergency, so that the State Water Coördinator, who will be working with that Safety Council will be at the State Control Station in the event of an emergency.

The State has been divided into ten districts—each district has a chairman to coördinate all the local defense councils within his area. The District Medical Officers will relay all questions on to the State Public Health Department. State civilian defense officials themselves are sending on any questions on water supply protection to the Public Health Department. There is no division of opinion as to how that should be carried out.

There is no problem of boating on reservoirs. There is a ques-

tion of cutting ice. We do not approve ice cutting on reservoirs supplying domestic water. If the local officials want to do that, they have to assume the entire responsibility for the people who come in to work. They would not be authorized visitors. I heard from one place that they did have to permit ice cutting, and they have assumed the entire responsibility. They have an employee of the water department who will act as a guard and will supervise the actions of the workmen.

The matter of inventory of supplies, personnel and equipment will be handled through the State Public Health Department. There is no Water Works Association in Vermont.

Coöperation, so far, has been good; not as good as we would like to have it, however. Defense industry areas should have better guarding, and I believe they will come along as quickly as it can be explained to them that they should do it.

The matter of chlorination is being freely discussed. There are a great many places that have not chlorinated in the past. We have been advising those places to chlorinate. We cannot order them to, unless we can show cause. Results of analyses showing practically no contamination have been against us so far as advising chlorination is concerned.

Earle Devendorf.* On October 14, the Governor of New York ordered into effect a state-wide mutual aid plan for water service. We have had no special legislation, but legislation has been agreed upon and will probably be introduced within the next week or two, but there were a number of things which could be done without waiting for it. The plan as recommended to and approved by the Governor provides that the state be divided into 23 zones, that a zone coördinator be appointed over each zone, and that our District Engineers be appointed Assistant Coördinators. In the appointment of the coordinators, an outstanding water works superintendent in each zone was selected. Among the objectives of the program as announced to the coördinators, was one calling for promotion to the fullest possible extent of interconnections with adjoining or neighboring municipal water supplies and other approved water systems, so that in the event of failure of one supply, continuation of water service could be

*Water Coördinator, New York, and Associate Director, Division of Sanitation, N. Y. State Health Department, Albany, N. Y.

assured by the other. Before I will approve any interconnection, I am clearing plans through the underwriters and they have agreed to assume that responsibility. The New York Fire Insurance Rating Organization, which deals with smaller municipalities, has records of most systems. The question of interconnections with industrial supplies is also a very important one, but no such connection can be made without the approval of the State Health Department.

Another objective is to have each local water authority prepare maps or bring existing maps of distributing systems completely up to date. Machinery has been set up to have such maps prepared or to get them, through the State Water Power and Control Commission, or through the fire underwriters.

Another objective is to coöperate with the fire authorities. We have found it very desirable to give the fire authorities a place in this picture. I became impressed with the need for this last winter when at the invitation of Mr. Weston, I spoke at one of the meetings of this Association. I was preceded by the Fire Chief of Boston who made it apparent to me that Boston was far ahead of any other municipality in the country, so far as coördination of the work of the water department and the fire department was concerned.

Another objective is to coöperate with the power companies. In our Long Island area, during the hurricane, several water supplies were disrupted because of failure of power lines. One of the crying needs is for auxiliary sources of power to assure continuation of water service.

In regard to our proposed legislation, the first idea was that it should be temporary, for the emergency period only. Now the thought is to make it permanent legislation to deal with disasters, so that obviously we ought to make a start toward some of the long-range objectives.

The Governor has appointed the Lieutenant Governor as State Defense Coördinator and has set up local county and city defense councils. These local defense councils are made up of fine individuals, but they know little or nothing about water. In the latter part of September, I went through the southern part of New York, and in four municipalities I learned that they had received a letter from some defense agency to the effect: "Please advise when you are ready to have a proficiency test made of your water supply by having

thirty per cent of your hydrants open." I was greatly disturbed by that because I knew there isn't a water system that could stand that. You would simply drain your system dry and have no water supply. The way to correct that—and we have taken steps to do so—is to have the local defense councils clear everything dealing with water supplies through the zone water coördinator in the area.

Another objective is to take necessary precautions against sabotage and finally to have a detailed inventory of personnel, materials, supplies and equipment made by each local water authority to the zone coördinator to facilitate the interchange of needed supplies in event of emergency. We have had those inventory forms coming in.

In our early contacts with some of the zone coördinators, particularly in Westchester County, I was advised by the zone coördinators that there were objections to interconnections. You can't have too many interconnections. Unless we try to do something about correcting deficiencies in fire protection, we may be held partly responsible for any catastrophe that may occur. Now the great difficulty is the question of financing. I've been advised by the Governor that the state has not yet come to the point where it can provide funds. I understand that in England the government underwrites fifty per cent of the expense of interconnections and that the government has authority to require their installation. In New York State it may be that funds will be provided by W. P. A. or under the Lanham Act or by local authorities.

In the matter of providing guards for water works, this has troubled us. We have about 800 to 900 water supplies serving 1200 communities in the state. We have about 130 so-called defense-connected supplies. On the question of protection, I collected data from the American Water Works Journal and compiled all the information I could get from various sources and sent it out to zone coördinators for local distribution. About two weeks ago, I went to the Army and showed that material to them—G2 which is intelligence and G3 which is operations—and they said that they had nothing to suggest. Problems have arisen concerning guards. I have had a letter from an official of one of the larger water companies, stating that he was having difficulty in getting pistol permits for some of his employees, although it had been recommended by the local police department that these guards be armed. The promiscuous arming of people is

objectionable, since persons without proper training may get excited. You are dealing with the human element. My own home town—Schenectady—has put on 22 armed guards at critical points. Pumping stations have been fenced off and flood-lighted with the General Electric Company's advice and assistance. Yesterday, I was told by one of the representatives of the Western New York Water Company of the experience which they had had with guards that were put on by the sheriff's office. Their own company representatives went in and found the guard asleep. Don't kid yourself that just because the guard is there, you're protected. He has to be checked.

LEONARD W. TRAGER.* On the question of inventories of materials and equipment that are being compiled in the various states, it is believed that, in addition to their use in times of war emergency, they can also be valuable for long range planning and use. In that materials are becoming harder and harder to obtain, also because the carrying of large quantities of repair stocks ties up a large amount of money, it does seem that perhaps three or four cities or towns grouped together could pool some of the larger items normally carried in the inventory. Such a pooling of stocks, particularly those items necessary for repair but rarely used, could be of great benefit to such communities.

MR. CHASE. Apropos of Mr. Trager's remarks, I think it well to bear in mind that a great many of the procedures and plans that are being laid now in times of war emergency are applicable in times of floods, hurricanes and other emergencies, so that a good deal of this effort to prepare for wartime emergency is well worth while in connection with the disruption of service due to other causes. The matter of inventories and cooperation between departments is an example of that sort of thing.

I am going to introduce this subject of chlorination under emergency conditions by calling attention to the fact that orders or instructions or recommendations have come from the Surgeon General's office advising the carrying of high residual chlorine throughout the distribution systems.

MR. TARBETT. I don't know of any better way to protect our water supplies against intentional or accidental pollution than by chlorination, although I knew you could not all run up your chlorine.

*Assistant Sanitary Engineer, New Hampshire State Board of Health, Concord, N. H.

England is carrying plenty of residual and there is plenty of odor. I am not worrying about OPM. We have to have chlorine and it must be supplied. But I am interested in more thought being given to chlorination to see if we can work out these newer methods, so that we can carry a good chlorine residual without taste or odor.

We have three things that may affect distribution systems. First, there is the possible intentional addition of pollution. Second, with the increased demands of plants and industrial areas, there is the probability that there will be a slip somewhere in protection against pollution. Third, there is the possibility of sabotage. Sabotage does not mean action by an enemy entirely. It means carelessness or anything that may impede military activities. Unless you chlorinate you may have pollution in the mains. If there is some chlorine residual in the distribution mains, the danger of accidental or wilful pollution is reduced to a minimum—consequently we have recommended to the state health departments that they urge the water departments to boost their chlorine application.

WARREN J. SCOTT.† If Mr. Tarbett means that he recommends carrying chlorine residuals throughout the entire distribution system, I think his recommendation is entirely impractical because in areas where you have soft water with a small content of ammonia, you can't carry chlorine residuals to the point suggested without adding ammonia. If you are going to use ammonia, you have to buy ammoniators. We would also have to get new chlorinators as the capacities of present machines are insufficient. In London, which Mr. Tarbett mentioned, they are constantly in danger of having their mains broken by air attack and disinfection is a measure to parallel or reinforce notices to boil water. I agree with Mr. Tarbett, however, in his recommendation to increase chlorine residuals at the point of treatment as a safety precaution. This is entirely practical.

I would like to mention briefly the policing situation in Connecticut. In Connecticut, 80 per cent of our water supplies are privately owned. The Public Utilities Commission and the State Police Department have been giving careful consideration to measures for protection of water utilities. Arrangements are being made whereby an engineer of the Public Utilities Commission, a trained police officer

†Water Coördinator for Connecticut and Director, Division of Sanitary Engineering, State Dept. of Health, Hartford, Conn.

and a sanitary engineer from the State Department of Health are visiting every plant and, as a result of their surveys, the Public Utilities Commission and the State Police Department are making recommendations as to the forms of protection that they feel should be carried out. The Public Utilities Commission has advised all private utilities that consideration will be given, if necessary, to the expense they will be put to in providing for necessary policing. I think we are getting a workable system, although the private utilities officials at one or two meetings have expressed the one view that eventually the cost for this policing should be borne by the Army.

MR. WESTON. One thing that is concerning all the water works men as much as anything else is the possibility of getting chlorine and chlorine compounds.

MR. CHASE. It has been estimated that carrying and increasing the chlorine application to the public water supplies throughout the country would increase the demand for chlorine from about 3 to 4 per cent of the total production of chlorine now being delivered, to something like fifteen per cent. If those figures are correct, it is a real problem to get the chlorine.

FREDERICK S. GIBBS.* Mr. Gibbs pointed out that standby emergency chlorination equipment would be worthless without chemicals, that while water utilities using hypochlorites regularly were assured of sufficient supply for normal requirements, there was some question as to the availability of these chemicals for emergencies, particularly in the case of the larger water utilities.

Mr. Gibbs referred to the orders issued by OPM in the matter of materials for maintenance, repair and operation, and for major capital additions. This discussion is not given here due to changes in Federal organization and orders.

HENRY ARMBRUST.† Mr. Armbrust confirmed Mr. Gibbs' statements that regular users of hypochlorites would continue to receive supplies thereof and quoted information received from OPM. This information was to the effect that the OPM had given a preference rating of A-2 to chlorine for the treatment of potable water and for the manufacture of products for treatment of potable water and that no difficulty was anticipated in supplying requirements for this use

*Coördinator of Supply of Water Treatment, Chemicals for Massachusetts and Engineer with Wallace & Tiernan, Inc.

†Proportioneers, Inc., Providence, R. I.

although high-test calcium hypochlorite might not be readily available due to limited production.

MR. CHASE. This discussion this morning seems to have brought our four C's by which we can combat one of the four horsemen of the Apocalypse—the horseman of pestilence. Those four C's are coöperation, coördination, common sense, and chlorination mixed with common sense.

COORDINATING THE FIRE SERVICE

BY P. C. CHARNOCK*

[*Read February 19, 1942.*]

To coördinate means "to put" something into harmonious relationship. My experience over a rather long period of years indicates a most satisfactory relationship in the fire service. Whenever a call has come for assistance at large fires, a municipality willingly has sent its apparatus to an adjoining city or to a distant city, if need arose. In fact, sometimes a fire department was so anxious to get into the fight that it responded to help its neighbors without an invitation.

The problem today, however, is to weld this large force of fire fighters into units so that there will be an orderly movement of apparatus and men when the call arises. Municipalities will still maintain their integrity and local fire organizations but, by mutual agreement, will send apparatus and men to any place they may be called. When this happens some other community will move some apparatus into the vacated territory. This means no community should be without some apparatus except for the time that it may take to travel from one town to another. Of course, this will result in a thinning out of apparatus, and it may occur over a rather extensive area, depending on how serious the spread of fire may be, either a single fire or a number of simultaneous fires. Naturally, the first thing to do in such an occurrence is to take account of stock to ascertain what facilities and how many of them are available for the purpose.

Some years ago a canvass of this nature was made in this commonwealth, and much valuable material was collected and tabulated, but unless this is done periodically it fails of its purpose. Early last summer a similar summary of equipment was gathered. By referring to this tabulation, one can quickly find where various pieces of equipment can be obtained, if wanted at any given point, not merely in case of fire but for any emergency, such as the floods that we experienced only a few years back or hurricanes such as have visited us and may again come to us.

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*State Fire Coördinator for Massachusetts.

Following this, in September, the Office of Civilian Defense sent out questionnaires to every municipality seeking information as to the number of various types of apparatus in service, such as engines and their capacity, hose wagons, ladder trucks and special apparatus; also the age of each of these. These municipalities were also requested to state how much additional apparatus they should have for peace time service and again under war conditions.

The replies concerning existing equipment were mainly satisfactory, but as to the added equipment required under the two conditions specified, this was practically valueless. Some places failed to specify anything, principally because they had no conception of their needs; others who never before felt they needed anything more than they had called for practically everything that could be imagined. As things have since developed, this requested information was needless anyway.

You probably have had experience in obtaining information by sending out questionnaires. Well there were quite a few places from which no returns were received on the date specified. But by the cooperation of the State Police we were able to have the local authorities fill out the blanks on the spot and the tabulation completed. From this we have prepared a map of Massachusetts which will show at a quick glance how much apparatus is located in each municipality. Also from this we can see how many pieces we could afford to move in case of fires in any given area.

Just as this study of movement of fire apparatus was under way, a serious fire visited a freight yard area of Boston where immense quantities of canned foods were stored in four freight sheds. Five alarms were sounded, and as the fire appeared to be out of control, frantic calls were sent out throughout the state to send all available apparatus to Boston. Soon pumpers from many places, some as far distant as 30 miles, were on their way. Some cities who sent apparatus could ill afford to do so. In all, 55 pumpers were at the scene; many could not help as all of the hydrants near enough to the fire were in use and the pumpers attached to them were already directing sufficient water onto the fire to control it.

It was then resolved that this occurrence should not again be repeated. Plans since developed call for outside aid to respond automatically to Boston only when five alarms are sounded, and then nine

contiguous communities will send ten pumpers into that city, not to the fire but to fill in vacated Boston stations. All of these cities have interconnections of their fire-alarm telegraph systems, and provisions are further made that telephonic communication can be held over the fire alarm circuits if desired. This may prove of considerable value if our commercial telephone service is disrupted or overloaded with calls. The arrangement of moving in apparatus will then provide sufficient companies to handle a second-alarm fire anywhere in the city and numerous single-alarm fires should they occur subsequently. This plan does not weaken the adjoining cities to any degree, and supplementing the plan, they would send additional apparatus on call. By agreement, communities adjacent to those sending aid to Boston would send a pumper into some of these vacated stations so that finally no city would be lacking more than one of its usual complement of apparatus.

Equally serious fires could develop in other parts of Metropolitan Boston or in other parts of the state. Similar mutual aid arrangements have been made to dispatch apparatus if needed, but here this cannot always be accomplished automatically, as there is not the same amount of interconnection of fire alarm systems and the apparatus must be called by telephone. This is all a voluntary agreement among the fire chiefs in these communities. Yet there are some municipalities in the state where the fire chief does not have the legal right to send his men or apparatus to another city without first receiving authorization from his mayor and in towns by the board of selectmen.

In the emergency act passed during the 1941 session of our Legislature, the Governor is given power to order fire apparatus to any city if the need arises. In all probability he may find it desirable to issue some formal order covering this so that any fire department can legally fulfill the voluntary agreements already reached. It is, of course, understood if we have a blitz here—the recent developments all point to the possibilities of one—the usual assignments of several pieces of apparatus to a fire cannot be maintained. As a matter of fact, the blitz could take the shape of a series of fires by sabotage. In a blitz or in a series of fires, apparatus must be dispatched, possibly only one piece, depending on how frequently the calls come for assistance. Yet the same general scheme of bringing apparatus in from outside the fire area will be utilized.

To compensate for the possibility of increased fires and alarms, every community has been organizing and training auxiliary fire companies. In all, there are now some 1700 trained auxiliary firemen and 800 under training. At the outset we were led to believe that we should augment the regular fire departments by as many as 11 times the existing companies; then the figure was reduced to 3 times and as I will later bring out, only one for each existing pumper.

Until the Pearl Harbor attack there was a general feeling of apathy and complacency in regard to the situation. However, in some places auxiliary apparatus has already been puchased and equipped with hose and other fire-fighting devices. Probably many others would have done so but the Federal government had announced that some form of aid would be provided. The sad part of this is that none has been forthcoming as yet. This would not be so unfortunate if our normal fire apparatus was all in good condition and we could quickly obtain parts to make necessary repairs and to replenish our hose supplies. The tabulation of apparatus previously referred to showed that over 40 per cent of all pumpers in the state in 1941 were obsolete and in need of replacement; 1942 is fast getting away and this percentage is now higher. This comes about due to those who held the purse strings on expenditures refusing to appropriate money for replacements. This may, perhaps from some angles, have been justified as every city has been burdened with high tax rates due to the depression. I maintain, however, that when it comes to curtailing on public fire protection, be it fire apparatus, fire alarm or water supply, this is false economy.

I just want to give you one illustration, without mentioning the location, of the possibilities in respect to over-age apparatus. Not long ago a serious fire visited this city. Outside aid was called from a number of other places. Three of the eight pumpers in this city broke down and one of the ladder trucks was disabled during the fire. One pumper was later repaired so that it is now in service; another had a second-hand motor installed in it, but the third is still out of service. The ladder truck has not been repaired, and since then a second ladder truck has failed and is out of service. I do not doubt that similar situations may develop in other cities if they encounter fires that require full output of the pumpers and over an extended period of time.

Local fire departments which now have the money, and practically every city and town now is clamoring for apparatus and hose, are unable to obtain deliveries. Even on orders placed some months ago deliveries are held up. This is due to priority orders for the Army and Navy establishments and defense industries and more lately to the inability to obtain vital parts. I understand that there are only two concerns who are able to furnish transmissions and only a part of their production can be obtained by the fire apparatus builders. Within the week an announcement has come from Washington that some places within 300 miles of our coast lines are to receive fire pumpers, hose and equipment on a loan basis, this to come from the so-called $100,000,000 appropriation when and if passed. It has not as yet been determined where this distribution is to be made, but it is assumed it will be where it is most needed. The distribution arrangement under this plan is that one pumper will be provided for each operating pumper, plus one for each pumper over 15 years old. The joker in this is that the fire department must find the necessary second-hand truck chasses on which to power or mount the pumps and equipment.

We all appreciate the necessity of turning every available means to the production of war material but when the fire departments are starving, so to speak, in regard to replacing wornout apparatus and are expected to develop a second line of defense, it seems almost incredible that they must turn to using second-hand power plants that may turn out to be duds when they are put into action.

After this $100,000,000 appropriation is made available, the government then can place orders for the pumpers and equipment, but it will take a long time to equip all of the communities requiring apparatus. Nearly 700 pumpers will be required to fulfill the formula just for the places of 10,000 population or over in the Commonwealth of Massachusetts.

The rubber and the critical metal shortage hits the fire hose for everybody. To cope with this, it is planned to furnish hose with only a single jacket instead of the usual double jacket of cotton fabric; to use malleable iron couplings instead of bronze and some reclaimed rubber instead of pure Para rubber in the hose lining.

We believe that the fire problem here is more serious than in England even if only a fraction of the aerial attack is waged on us

than they have had over there. With our large proportion of wooden construction in cities that actually have been built to burn, it seems that it would be almost impossible to avert sweeping conflagrations. We are told that when Coventry was attacked a convoy of 100 pumpers was sent from London to help fight the fires. If we had to send 100 pumpers today to help out Boston or Worcester or Springfield or any of our industrial areas, this would put a terrible dent in our available apparatus. The men in the fire service realize the gravity of all of this and I want to pay tribute to them. As an illustration of their feeling of responsibility, the entire group of New England fire chiefs voted last week to postpone indefinitely their annual conference in the belief that they should stand by the helm and be ready when the call to service is sounded.

While everything possible has been done in making arrangements to send apparatus to any place that may require it and large numbers of men have been trained as auxiliaries, the fact remains that we are not equipped to meet the enemy as we should be and we do not know when we will be. I have purposely outlined the situation to you as I view it since I believe that you and the public as a whole should be aware of the situation. My sincere hope is that recent developments in Washington may expedite the solution of our problem and that we can get down to the business of turning out fire apparatus and equipment that is sorely needed, not only in Massachusetts but in other parts of the country. It is of but little avail to organize and train an army of fire fighters and then give them a broomstick to fight with. I will say this, however, that when the time comes—and we pray it will never come—you will find the men in the fire service right on the job ready to go into the battle as did the gallant men of Concord and Lexington. If their only weapon is a bucket of water they will swing it willingly, unceasingly and effectively.

EXPERIENCES OF THE SANFORD WATER DISTRICT IN WATER TREATMENT

BY HORACE L. CLARK*

[*Read September 25, 1941.*]

The Sanford Water District supplies water to the town of Sanford, which is located in southwestern Maine, a hundred miles north of Boston. Sanford has a population of approximately 15,000. The principal industries in the town are those of the Goodall Worsted Co., sole manufacturers of Palm Beach cloth, and the Sanford Mills, manufacturers of plush upholstery, and two shoe factories. The chief problems of the Sanford Water District in water treatment are iron removal and the retardation of corrosion in the distribution system. A brief outline of the supplies of the District and its predecessor companies will give the necessary background for a better understanding of these problems.

The Sanford Water District started operations in 1931 and was formed by the consolidation of the Springvale Aqueduct Company and the Sanford Water Company. The village of Springvale is part of the town of Sanford, but had had its own separate water supply since 1878, when water was taken by gravity from Littlefield's Pond and supplied to Springvale through a pipe line, which consisted of bored logs with metal sleeves connecting the separate lengths. The wooden pipe line was replaced many years ago, but this gravity supply is still in use. The water is treated by passing it through a slow sand filter and sterilizing it with chlorine and ammonia. There is also an auxiliary pumping station above the village of Springvale which takes water out of the Mousam River. This supply was used by the Springvale Aqueduct Company when Littlefield's Pond was low and is still available as a stand-by, but has not been used since 1931, as any deficiency in water in Springvale was furnished from the Sanford supply.

The earliest supply for Sanford consisted of a well and a windmill installed near the center of the town in 1886. This proved inade-

*General Manager, Sanford Water District, Sanford, Me.

quate in a few years, and after a search for additional supply, the Sanford Water Company erected a pumping station in 1897 on the Mousam River approximately a mile north of the town, toward the village of Springvale. The original supply came from four 6-in. wells which were housed in the pumping station building. In 1911, additional water was secured from some wells and springs across the river from the pumping station. These are located in a collecting gallery and are covered by a frame building. These two sites furnished sufficient water for the needs of the town until 1926, when an additional supply was obtained by driving thirteen 2½-in. wells in the area adjacent to the pumping station. These wells gave an abundant supply of water, but unfortunately the water had such a high iron and carbon dioxide content that serious "red water" trouble developed shortly after this source was turned into the system. Attempts were made to correct this situation by installing a small tray aerator, which reduced the carbon dioxide content slightly, and by shutting off those wells which showed high iron content. The swampy soil which covered the area in which these wells were driven was removed and replaced by gravel. These measures, however, did little to remedy the trouble.

This was the situation in 1931 when the District took over the operation of the two properties. Each of the three supplies had some drawbacks. The gravity supply from Littlefield's Pond furnished approximately 150,000 g.p.d. and could not be counted on for more than that except for short periods of time. The auxiliary supply from the Mousam River required filtration before it could be accepted for permanent use. The well supply at Sanford had a capacity of 1,000 g.p.m., but the water had an average iron content of 1.0 to 1.5 p.p.m., a carbon dioxide content of from 20 to 30 p.p.m., and a pH of 6.1.

The District drove quite a few test wells in various locations in an effort to find a supply that contained less iron than the present raw water. Although some of these wells tested better than those in use, the formations encountered were practically the same, and it appeared that there would be danger of the amount of iron in them increasing after they had been pumped for any length of time. All of these test wells have been driven through gravel and sand by the drive and wash method and have struck bedrock at a depth of from 20 to 30 ft. These wells are 2½ in. in diameter, have an open end, and the

bottom length of pipe is drilled for a distance of three feet with a series of ¼-in. holes. These wells have shown a test delivery of 50 to 100 g.p.m. of water.

During 1934, five additional 2½-in. wells were added in the area near the Sanford pumping station. These provided temporary relief by reducing the average iron content of the water. The following season was comparatively dry, and the iron content in these new wells increased until the average amount of iron in all the wells was about the same as before the new wells were driven. As there is an abundance of water under the land near the pumping station, it seemed more practical to treat this water than to search for other supplies.

Many complaints were received due to rusty water, particularly on streets where there was no circulation. Pipe which was removed from the ground showed excessive tuberculation. The Trustees authorized the writer to study different methods of iron removal to determine which was the best method to apply to the Sanford water and also the most economical from the standpoint of original cost.

After considerable study, the writer recommended the installation of a Zeolite Iron Removal Plant and the District entered into a contract with the Permutit Company for three pressure filters 8 ft. in diameter by 5 ft. high, together with the necessary appurtenances. These filters contained a bed of 24 in. of zeolite on top of a 12-in. layer of gravel and had a total capacity of 750 g.p.m. The zeolite removed the iron by base exchange and was regenerated by a brine solution made from common salt. The filters were back-washed at the end of each run, and brine was injected into the filters which were then rinsed until all traces of salt were removed. The iron was removed from all the water taken from the well fields on the easterly side of the river. The water from the spring house on the westerly side of the river is low in iron content and was mixed with the water from the filters. These zeolite filters removed the iron from the water very satisfactorily, but we found difficulty in trying to maintain the pH of the water at a high enough point so that the zeolite would not disintegrate. We tried to raise the pH of the raw water by the addition of soda ash, sodium silicate, and later caustic soda but found that these treatments worked fairly well for a short period of time and then interfered with the action of the zeolite in removing the iron. As soon as the alkaline feed was stopped, the zeolite again

removed the iron in a satisfactory manner. Further experiments were therefore undertaken in coöperation with the Permutit Company. Three filters of household size were set up in the pumping station, one containing coarse sand and double the capacity of the other two. This was used as a roughing filter. Water from this roughing filter was then divided between one filter that contained manganese zeolite, which was regenerated with potassium permanganate, and another that contained fine sand. Air was injected ahead of the sand filter in order to oxidize the iron in the water. These two filters were used with the roughing filter and without it, and after a year's experimentation it was found that following the injection of air the fine sand filter gave equally good results on the Sanford water as either the manganese zeolite or the sodium zeolite. It was therefore decided to change from the zeolite to the sand and air process, and this change was made in June, 1940. The zeolite and the gravel was removed from the tanks and the gravel washed for re-use. The filter bed is now made up of 8 in. of gravel, 10 in. of coarse sand and 12 in of fine sand. The change from zeolite to sand necessitated an increased volume of wash water, and the brine heads were converted into a surface wash system. This arrangement has been in operation for over a year and has been giving satisfactory results. A recent examination of the sand in the filters shows the sand to be quite heavily coated with iron but not to the point where it is necessary to change the sand. The water leaves these filters with practically zero iron content.

At the present time, we are increasing the Sanford supply by driving thirty additional 2½-in. wells in an area about one-quarter of a mile from the pumping station. We have had three test wells in this area for several years, and they have shown a low iron content and a high yield. Water in this area has been near the surface of the ground all summer in spite of the unusually severe drought, and the test wells are not affected by the daily pumpage of the existing system.

Before the installation of the iron removal plant, it was not advisable to treat the effluent for corrosion control as undoubtedly the addition of chemicals would have thrown down more iron in the mains and led to more trouble. Hydrants and blow-offs were flushed monthly during the warm weather and as often as possible in the winter.

A decided improvement in the quality of the water was evident immediately after the iron removal plant was put in operation. The water lost its yellow tinge due to a content of 1.0 to 1.5 p.p.m. of iron and came out blue and sparkling. The problem then was to deliver the water to the customers in the same condition and to prevent it from picking up too much iron from old mains that were badly tuberculated.

Tests showed that a pH of 9.75 was required to give theoretical protection by lime treatment. As the analysis of the raw water showed a pH of 6.1 and a carbon dioxide content of 20 p.p.m., it was apparent that the amount of lime required would increase the hardness from 16 p.p.m. to an undesirable amount. The District therefore experimented with sodium silicate, soda ash and caustic soda in various doses. Caustic soda gave good results in the reduction of carbon dioxide, but gave rise to an undesirable taste. Neither sodium silicate nor soda ash produced as good results alone as in combination. The District has now settled on a dosage of equal parts of soda ash and sodium silicate in amounts which raise the pH of the effluent to at least 7.5. During the past year, samples have been taken weekly at seven sampling points, four of which are on dead ends farthest away from the pumping station. These have, with one exception, consistently shown an iron content of not more than 0.2 p.p.m. for the past four months.

On the basis of these tests, the small amount of flushing required, and the small number of complaints, the District feels that it is delivering a satisfactory soft water to the consumers. Further study may lead to some changes, but corrosion is at least retarded.

Discussion

Linn H. Enslow.* Will you please describe the mechanics of aerating the water and getting rid of the air?

Mr. Clark. We use a regular, garage-type compressor and inject air into the header that goes to each filter. An air cushion is maintained on top of the filter so that we know that there is air present at all times. As the water comes out of the ground the iron is in the ferrous condition, in solution. By the addition of oxygen from the air the iron is oxidized to the insoluble ferric state. The

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air that accumulates above the sand is bled off before washing the filters. An air valve is set on top of the filters which will automatically discharge if the air pressure is built up too high.

WILLIAM W. BRUSH.† What is the pressure in the filter tanks?

MR. CLARK. The incoming pressure is between 16 and 20 lb. per sq. in. and the outgoing around 8 to 10 lb. per sq. in. We inject the air at about 30 lb. per sq. in.

†Editor, Water Works, Engineering, New York, N. Y.

LAYING SUBMARINE PIPE IN PORTLAND HARBOR IN WINTER

BY HARRY U. FULLER*

[*Read September 23, 1941.*]

Among the islands that protect Portland Harbor from the waves of the Atlantic Ocean are Peaks Island and Cushing's Island. Three thousand feet of water separates them, and this stretch of water is subject to all of the weather of the open ocean.

The Portland Water District supplies Peaks Island with year-round service through buried pipes and has for some years supplied Cushing's Island with summer service through a 3-in. pipe which was not protected from freezing and had to be shut off and filled with sea water during the winter. The United States Government had fortifications on Cushing's Island which had been practically abandoned for many years.

In the fall of 1940, the War Department decided to improve the existing buildings and build more barracks, with the intention of having several hundred men stationed at Fort Levett. There was a water works in the fort consisting of a loop of 6-in. pipe, a small concrete standpipe and reservoir, with a pumping station getting water from drilled wells. The water from the wells was of poor quality and inadequate in quantity.

Preliminary Investigation. The Portland Water District, at the request of the Constructing Quartermaster's Department, made a survey in August to determine the feasibility and cost of an 8-in. water main from the 8-in. main on Peaks Island to the system on Cushing's Island.

It was found that a line between sand beaches on each island would, except for about 300 ft. on each end, be in clay and that no ledge would be encountered. A small lighter was used, from which soundings of the depth of water and the type of underlying material was learned. A 1-in. steel pipe in 10-ft. sections was used to get the depth of water and indicate the quality of the underlying material. The water at high tide was about 40 ft. deep in the channel near the Cushing's Island shore.

Type of Contract. In October of 1940, the Constructing Quar-

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termaster's Department asked the Portland Water District to undertake the construction of the line, which the District agreed to do at cost to assist in National Defense. The only contract was a telegram from the Boston Army Base Constructing Quartermaster saying in substance: "Build the line and Uncle Sam will pay for it."

Materials Used. Experience with previous underwater lines in Portland Harbor had taught the great importance of a line that would be hard to pull apart, and steel pipe with two lugs welded to each end of 40-ft. lengths was purchased. The pipe was centrifugally lined inside and coated and wrapped on the outside. Dresser couplings were used at the joints and cadmium-plated bolts held the adjoining sections of pipe from pulling apart. These bolts were located on the horizontal axis of the line when laid, and this allowed for a small amount of vertical movement.

At three points in the line, where greater deflection was desirable than could be safely made without straining the couplings, Moran joints were installed. These ball and socket joints permitted a 20-degree deflection. At the high-water mark on each shore, slip joints were inserted, permitting a 10-in. change in length.

Method of Construction. Owing to the heavy swells and winter storms and the advantage of not having to hunt to find the trench, it was decided to drive a row of piles about 40 ft. apart on the line, excepting for about 200 ft. on each shore and a gateway about 200 ft. wide in the channel. Several brace piles were driven at many of the line piles to provide strength to hold lighters in position. The line of piles was 8 ft. from the pipe line and permitted dredging the trench while the lighter lay along side the piles. The general order of the work was to drive the piles, dredge a trench, lay the pipe, and finally backfill the ditch and remove the piles.

Since it was necessary to maintain a gateway in the line of piles at the channel, the first step in pipe laying was to join together about 200 ft. of pipe and suspend this section from floats. To each end, a Moran joint was connected, and beyond this a section of 150 ft. of pipe was added. When the middle of the line was in the trench, the Moran Joints permitted both ends of the pipe to extend above low water. From this point the procedure was to connect on another length of pipe and lower it to a point just above the water level.

Equipment. A pile driver 24 ft. by 54 ft. with power and a steam

hammer was employed to drive the piles. A lighter 28 ft. by 80 ft. with an 80-ft. boom on one end was furnished with a smaller derrick rigged with a bull wheel on the other end for dredging.

Three buckets were found to be desirable in the different kinds of material; a one-yard clamshell, a 5/8-yd. clamshell with teeth, and a 5/8-yd. orangepeel.

A lighter 48 ft. by 18 ft. was used for pipe laying. Two motor boats and a tug completed the floating equipment.

Driving Guide Piles. The number of piles used for guide piles and brace piles was 155. Seventeen days of elapsed time was required to drive the piles and raise cables in preparation for dredging, and the average was therefore 9 piles daily. The piles ranged in length from 30 to 70 ft. and averaged about 45 ft.

Dredging. Dredging proved to be the slowest part of the work. The dredging was begun as soon as the guide piles were in place and continued to the last day of pipe laying. An orangepeel bucket would fill up in the clay that was present over a large part of the line, while a clamshell bucket with teeth was needed to break the packed gravel at each island shore. The bucket left the bottom of the trench somewhat uneven and it was leveled by dragging a mushroom anchor along the trench. The anchor was supported by a dory at an elevation calculated to shave off the high spots in the bottom of the trench and was dragged toward the lighter by a long line.

Sixty-eight days elapsed during the dredging of the 2800 ft. of trench, giving an average of 41 ft. for each day.

Strong Backs. One of the chief elements in the successful laying of the pipe was the use of strong backs at every joint. An 8-in. steel pipe has considerable stiffness, but due to the depth of water the pipe was unsupported for a distance of about 200 ft. It was necessary to support the pipe at each joint, and while rafts might have been used, it seemed a better solution of the problem to strap on top of each joint a piece of timber 10 in. by 10 in. and 8½ ft. long. Four iron straps were used at each joint, with the two center straps long enough to permit the allowable 4-degree deflection in the Dresser coupling.

Lashed to the top of each strong back were two empty oil barrels to provide buoyancy. This procedure resulted in a steel tube that when full of water weighed very little and was strong enough to stand the strains to which it was subjected until it finally rested in the trench.

After testing to know that there was no leakage and that every joint seemed to be perfect, holes were punched in the oil barrels with a sharp-pointed piece of iron at the end of a ¾-in. sounding rod. As each hole penetrated the oil barrel, the bubbles rising to the surface gave notice that the line had lost its buoyancy and could be expected to stay down even if unwatered.

It was even more important to provide strong backs for the Moran joints to be sure that they had not exceeded the allowable 20-degree deflection until they were resting in the trench.

Pipe Laying. The first pipe laid was the section 500 ft. long, which was connected together on rafts in a cove at the Cushing's Island end of the line. When this line of pipe was all connected and supported under rafts made of oil barrels and the tide was slack and little wind was blowing, the section of pipe was lowered into the trench. This was accomplished without trouble, and from this point on the procedure was to connect on another pipe and lower it to the water surface.

At each end of the line near high water, the pipe was laid at high tide from the lighter, and at low tide the work was completed by a crew on the beach.

The procedure in laying most of the pipe was as follows:

While the end of the completed section of the line rested on a float or dory, the next piece was swung into place by the derrick on the pipe-laying scow and held in position while the Dresser coupling was installed and the two harness bolts placed. Then a piece of strong kraft paper was fastened around the joint and held with wire to form a trough into which melted bituminous material similar to that used in coating the pipe was poured, covering all the exposed metal and coupling. The next step was the installation of the strong back and finally the empty oil barrels, after which the pipe line was lowered until the end rested once more on the float.

Pipe laying required 47 elapsed days for the 2800 ft., or an average of 60 ft. each day.

Cables. Several submarine cables leave the shore of Cushing's Island and cross the water pipe line. It was necessary to pass the water pipe under the cables, and this was accomplished by bringing the cables together and supporting them on piles and a float while the trench was excavated and the pipe laid.

Testing. Before a trench was backfilled, and when the pipe line was completed between low water marks at both islands, it was tested for tightness at a pressure of 100 lb. per sq. in. The apparent leakage was negligible and probably largely due to not taking time to get all of the air out of the pipe.

Time Required. On November 6, 1940, after a week of preparation, the first guide piles were driven, and for the next 98 days the prosecution of the work was a constant fight with storms, high waves, and freezing weather. On the 98th day, the line was chlorinated and the water turned on, and on the following morning boat loads of soldiers arrived on the island. Thirteen more days were spent in backfilling the trench and removing the piles, and finally, on February 25, the work was complete. Out of the total 111 days required to do the job, 22 days, or 20 per cent of the time, were lost due to weather conditions.

The cost of the work, including labor, rental of equipment, material, insurance and overhead was as follows:

Item	*Total Cost*	*Cost per Linear Foot*
Driving piles	$ 5,931	$ 2.12
Removing piles	1,216	0.43
Dredging	22,972	8.20
Backfilling	5,723	2.04
Pipe	7,049	2.52
Pipe laying	7,098	2.54
Lost time	2,182	0.78
Total	$52,171	$18.63

Personnel. A contract was made with Raymond F. Bennett, President of the Bennett Contracting Corporation of Portland, Me., who had previously done similar work for the Portland Water District, to furnish the necessary floating equipment and crew and to give his personal attention to the execution of the work. The resident engineer in charge of the work for the Portland Water District was Charles R. Moore. The successful prosecution of the work was due to the untiring efforts of these men.

LINING A CONCRETE RESERVOIR

BY H. J. COOK*

[*Read September 24, 1941.*]

In the early nineties, citizens of Auburn, acting under a water commission, had taken by right of eminent domain the existing public water supply system which was owned by a private company. Up to that time, the owners had tried to operate the plant for the sole purpose of making a profit and had been only too successful. They were equally fortunate when the courts set the value of the confiscated system on the profit returned rather than the actual cost of the layout.

Included in the system was a small standpipe almost in the heart of the city, which would hold only a few hours' supply and at an elevation lower than many of the residences. In order to serve these homes, and to have adequate storage, it was evident that a reservoir must be constructed at a higher elevation. Land was acquired on the crest of a hill about a mile from the center of the city, and about 140 ft. higher than the old location. The hill itself was rather flat on top with outcroppings of ledge, mostly feldspar and quite seamy.

An eminent engineer of those days was hired, plans drawn, and the contract for the work was awarded. The result was a concrete reservoir in the shape of a square with two opposite corners cut off, making a six-sided figure about 930 ft. in circumference, about 18 ft. deep, and holding about 6¼ m.g. It was finally completed late in the fall of 1907.

In 1922, I assumed the duties of superintendent of the Auburn system. One of the first acts of the retiring superintendent to acquaint me with the plant was to take me to the reservoir and show me the leaks. Upon noticing my concern, he told me not to worry, as it had been that way for fifteen years and hadn't failed yet. Ditches had been dug to collect the water into one brook in order to keep the farmer who owned the land below from making too great a complaint. Charles Sherman, of the firm of Metcalf and Eddy, saw the conditions at this time. He estimated that at least 150,000 gal. of water was running to waste daily from one leak.

*Superintendent, Auburn Water District, Auburn, Me.

In trying to get information regarding the construction of that reservoir, I ran across more people with short memories than I ever knew existed. Although it was only fifteen years after, everybody on the job had forgotten all about it. The plans had disappeared completely. About two years ago, one of my lawyer friends brought in a set saying that he was going over some old papers in an estate and found them. They were of no value to us as the reservoir had not been built according to the plans anyway. However, gradually we were able to find out how the reservoir was built and the reason for the leaks. The accompanying sketch shows a cross-section of the wall as constructed.

Part of the work, especially the preparation of the site had been done at odd times by the water work's crew over a period of years. The concrete wall and part of the grading had apparently been let at contract. Evidently some sort of a trench or cut-off along the axis of the wall had been blasted into the surface of the rock. As there are areas in the surrounding outcroppings where the ledge has disintegrated so that it can be removed with a pick and shovel, we were rather skeptical of the value of such a cut-off. We were told also that the concrete was run late in the fall and that no protection against frost was provided. This was borne out by the spalling of the walls along the top and upper sections of the sides.

The real causes of the leaks, however, were the horizontal joints between the daily runs of concrete. This was due to the lack of knowledge of concrete construction in those days, rather than to any desire to slight the mixture, which was uniformly good. The inspector insisted that the laitance of the cement was the cream of it; the best part. Accordingly, at the end of each day's run, the concrete was worked and tamped until a thick scum of laitance was formed. On this, the next day's run was poured without any other bond.

Upon the completion of the walls, the earth and rock excavated from the interior of the reservoir was piled indiscriminately against the outside, this backfill not extending to the top. A concrete floor was laid on the inside, sloping towards the inlet. Until the work of last year, we were unable to get any information regarding this part of the structure.

At the end of the first winter, the reservoir was leaking badly. Cracks had appeared in the walls along the horizontal joints made by

the day's runs, many of them extending through the walls. Attempts were made to stop these leaks. Jute was calked in followed by lead wool, but the first winter ruined this. An asphaltic compound was tried without better results. By 1912, all connected with the water commission had become discouraged and it was a case of "leak darn ye, leak!"

Shortly after becoming associated with the Auburn Water District, I was visted by Charles Sherman. In order to get some excellent free advice, I showed him the problem. The result of that conference was the digging of a short trench in the earth outside of the wall and back-filling it with puddled clay. The result exceeded our expectations. From year to year, we extended this structure around the greater part of the perimeter of the reservoir. By that time the daily pumping had dropped by over 400,000 gal. But, the frost action always moved the clay and it was necessary to tamp it back yearly. The spalling of the walls continued. The ice action increased the size and depth of the cracks each year, until more and more of these extended entirely through the concrete. Quick-setting cement had been tried with only temporary improvement.

By 1940, it was evident that real repairs must be made. Mr. Sherman was called in as consulting engineer. It was agreed that about the only remedy was a coating of concrete to be applied to the inside and top of the walls, assuming that the cut-off trench in the rock was doing its job and that none, or only a small part, of the leakage was taking place through the bottom.

The contract to do this work was awarded to the National Gunite Contracting Company of Boston. The specifications were as follows:

1. Cut out all cracks and defective joints to widths ranging from 6 to 12 in. and in depth up to 6 in., depending on the nature of the concrete. On the floor, and about 2 ft. from the base of the wall, cut out a substantial groove into which the Gunite may be toed.

2. Remove spalled or otherwise defective and unsound concrete by means of pneumatic chipping hammers, carrying this into the structure until sound concrete is exposed.

3. All unchipped surfaces to be treated shall be thoroughly sandblasted.

4. Reinforcing shall consist of electrically welded galvanized fabric style 4 by 4, No. 6, No. 6. Sheets shall be erected vertically, starting at the cutoff groove on the floor 2 ft. from the toe of the wall. Sides of sheets shall be lapped by 4 in. and tied to each other with standard loop wire ties at intervals of about 18 in.

Mesh shall be tied to ¼ in. lead head expansion bolts set into the walls at necessary intervals, probably ranging from 2 to 3 ft. on centers. Mesh shall be maintained in position about 1 in. below the finished Gunite surface and shall be rounded over wall corners and at floor junctions where fillets are to be shot.

5. All horizontal cracks over 10 ft. long shall be additionally reinforced with a strip of fabric 2 ft. wide. This may be set into position before the main sheets are erected or following same, as we may elect.

6. Prior to application of Gunite all surfaces shall be thoroughly water and air blasted by the cement gun nozzle.

7. Gunite shall be premixed in the proportions of one part of standard Portland cement and three and one-half parts of clean, sharp and well graded sand. Depressions such as cracks, joints, etc. shall be first shot, following which the lining shall be built up in two body coats. The final or flash coat shall be applied after undue irregularities and lumps have been removed by screeding. At the proper time and before final set, Gunite that is to receive a subsequent application shall be screeded or dragged with a steel wire brush in order to remove the laitance surface.

Substantial fillets shall be shot at the junction of the wall and floor and at corners of the reservoir. Gunite shall be rounded over top edges of the walls.

8. Gunite shall be cured by constant sprinkling for a period of four days following its application.

9. It is intended that the final surface of the Gunite shall be approximately 2 in. from and parallel to the original concrete surface.

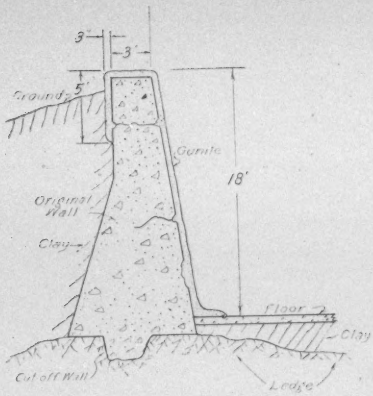
10. Expansion joints visible in the top of the wall shall be carried through the Gunite along the same plane. While the Gunite is still green, a groove shall be cut on the line of the joint about 1 in. wide and ¾ in. deep and later filled with hot asphalt.

The price for this work was 63½ cents per sq. ft.

When the reservoir was emptied, it was interesting to note that the fill at the back of the walls had become saturated with the leakage, and as the pressure was removed from the inside, this water seeped back into the reservoir. This gradually decreased and finally stopped. In the floor, the cracks showed damp, but very little water appeared.

Work was commenced on July 12, 1940 and proceeded rapidly, being completed on August 17, 1940. In the sand blasting and especially the chipping out of the cracks, we felt that the contractor really did more than his contract called for. This desire to do a good job was particularly noticeable in some areas where it was necessary to remove spalling concrete to a depth of at least two feet. In these places, the wall was rebuilt to the original line by the Gunite process without additional charge.

As the chipping of the top of the walls proceeded, it was found



that in many places the concrete had spalled to such an extent that it was decided to continue the Gunite surface over the top of the wall and down on the outside to a point below the penetration of frost. As no staging was required for this additional work, a price of 34 cents per sq. ft. was agreed upon.

As there were several large cracks in the floor visible, it was felt that it was good judgment to chip out these and refill with Gunite. The same was done to several small areas where the original concrete had disintegrated. A charge of $3.75 per bag of cement put through the mixer was made for this work. This price included the preparation of the concrete and the removal of all waste. It was in doing this part of the job that we found that the concrete floor was laid on a rammed clay subgrade in very good condition.

After the concrete was applied, a rather novel method was used to keep it damp while setting. The District had several hundred feet of old 2-in. pipe. In this 1/16-in. holes were drilled every foot. Then a line of pipe was laid along the top of the finished wall just at the inside edge, and attached to a water pump. This gave a continuous spray of water falling over the new concrete. We believe that the absence of haircracks in the finished work was largely due to this method.

When the reservoir was drained for the repairs, all water stopped

flowing in the ditches below. Upon refilling, no leaks were apparent. While we were pleased at this, we were still skeptical. It was the action of the frost during a Maine winter of which we were afraid. Accordingly, a boom of pine logs from 20 to 24 in. in diameter was floated inside the reservoir, and about 3 ft. from the wall. Several times during the winter, we inspected this and found that invariably the ice showed cracks along the boom. The logs had acted as rollers, or perhaps better as hinges. When spring came, the logs were removed and piled nearby ready to be replaced in the fall.

A weir had been constructed in the brook below the walls to check the leakage. Just before the reservoir was emptied for repairs the weir measurements gave a leakage of 120,000 gal. daily. Early this spring, as soon as the snow was gone, there was a daily flow of only 12,000 gal., a 90 per cent drop. We were entirely satisfied with that improvement. However, today the brook is completely dry. Evidently all leaks were effectually stopped and remained so during at least one winter.

The total amount paid to the contractor was $14,718.30, including all extras. After the reservoir was again put in operation, our records show a daily decrease in pumping of 134,000 gals. At the rate paid for electricity this means an annual saving in the cost of power of $625, or 4¼ per cent. As the District was able to issue bonds for the amount necessary at 1½ per cent, it can be readily seen that it was quite a profitable undertaking.

But all is not milk and honey in the water business. One of our customers is complaining because a wonderful spring in her cellar has disappeared. One of our own trustees kicks because the lily pond in his garden has become a dust bowl, and the farmer below the reservoir threatens us with suit because his wells have dried up.

EXPERIMENTAL TREATMENT OF RANCOCAS CREEK WATER FOR FORT DIX, N. J.

BY ROBERT D. MITCHELL*

[*Read September 25, 1941.*]

Not long ago the writer's firm was called upon to make a study of coagulation practices at the water treatment plant at Fort Dix, New Jersey. Certain aspects of those studies are believed to be of general interest to the waterworks profession as a whole and in particular to those members dealing with very soft, highly colored, surface waters. The remarks made here will be confined, so far as possible, to the test data accumulated in this study and will deal only very superficially with actual plant operation.

General. The water supply for Fort Dix is obtained from two sources. For many years, in the days when only a handful of troops occupied the Post during most of the year and summer camps lasted only a few weeks, the water supply was pumped directly from a branch of Rancocas Creek near New Lisbon, N. J. No raw-water storage was provided, and the only treatment was chlorination. With the onset of the defense program the number of men permanently occupying the Fort was increased tremendously. One of the first steps in preparing for their presence, so far as water supply is concerned, was the construction, from plans prepared by the Office of the Constructing Quartermaster, of a water filtration plant of 2-m.g.d. capacity which was believed large enough for any requirements of the near future. The plant was placed in operation early this year and almost immediately was forced to operate at as much as 200% of capacity. The alternatives available to alleviate this undesirable situation were the construction of additional plant capacity or the construction of wells. For reasons which will not be discussed here, wells were decided upon. Two wells each of about 1-m.g.d. capacity were drilled and are now supplementing the treatment plant in furnishing water to the distribution system.

This paper deals solely with the treatment of the surface water supply.

*Assistant Engineer, Malcolm Pirnie, Consulting Engineer, New York, N. Y.

Raw Creek Water. The water under consideration is an extreme example of the low-alkalinity, highly colored, very soft waters that are not uncommon on the Eastern seaboard. During the time in which the experiments reported here were being performed, the following analysis was typical of the raw water characteristics.

Color	90 p.p.m.
Alkalinity	0 p.p.m.
Soap hardness	10 p.p.m.
Carbon dioxide	8 p.p.m.

The pH of the water was low, probably between pH 4 and pH 5, but it was difficult to determine this colormetrically because of the unbuffered nature of the raw water. A partial record of raw water characteristics available at the treatment plant showed a remarkably consistent alkalinity and only a slightly less consistent carbon dioxide content. Color has been observed to vary from 30 to 220 p.p.m., large fluctuations sometimes taking place within a few hours.

Experimental Work. The experimental work consisted, first, of a study of coagulation, testing the alum and hydrated lime treatment being used at the treatment plant, and, second, of a study of other coagulants. The coagulation tests were performed in the following manner. A volume of 500 ml. of raw water was measured into each of a series of glass jars. Each was dosed with a concentrated solution of the coagulant and then stirred, usually for five minutes. As no stirring apparatus was available, each jar was twirled to induce rotation of its contents. Following this treatment, the sample was allowed to stand quiescent for one hour before being filtered through a Whatman No. 2 filter paper. The filtrate was tested for the constituents believed significant; then, in most cases, hydrated lime was added to raise the pH. Color, pH and, occasionally, alkalinity and hardness, were determined on the final product.

All tests were run according to Standard Methods of Water Analysis (1936), except that color was determined with a Hellige color disk, and residual aluminum was estimated by the hematoxlyn method as given in the section on "Non-Standard Methods", p. 255 of Standard Methods of Water Analysis.

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treatment plant effluent when the alum and hydrated lime treatment was being used, a rather extensive series of tests was run using the same chemicals, in order to determine, if possible, the reasons for the appearance of this indicator of improper preparation of the raw water. At this point, it might be well to state that we consider the presence of residual aluminum in a treated water the surest indication that the coagulation reaction has not occurred under optimum conditions. Further, the after precipitation and accelerated corrosion, which are not infrequently attributed to residual aluminum, are conditions to be avoided, if possible. A reasonable figure for maximum allowable residual aluminum has not, so far as the writer knows, been widely accepted. Experiences at West Palm Beach, Fla., have indicated that, under proper conditions, a residual aluminum content of over 0.05 p.p.m. is found but rarely. J. W. Kellogg[1] says of an extensive survey of the residual aluminum in the treatment plants of North Carolina that: "The record of well regulated filter plants shows that it is possible to average well below 0.05 p.p.m. at all times . . . "

Some question as to the proper order in which to add the chemicals led to preliminary tests in which the order of addition of chemicals was varied. Inasmuch as these tests indicated no observable differences in results, regardless of the order of addition, the experiments reported here were conducted by adding alum, stirring one minute, then adding lime, as 90% calcium hydroxide, and stirring for five minutes. Figures 1 and 2 show the results obtained. It will be seen (Figure 1) that satisfactory color removal could be obtained with 1 grain per gallon of alum or more, and that with doses of 1.25 grains per gallon or more a lime-alum ratio of from 0.15 to 0.45 gave good results. In general, the residual aluminum was low (Figure 2) only when the lime-alum ratio was between 0.25 and 0.45. This fact points to difficulties in plant operation if variations in the lime-alum ratio are possible.

Experiments Using Alum and Calcium Carbonate. It is an often repeated observation that the use of lime in the form of calcium hydroxide or calcium oxide to provide alkalinity in the coagulation of colored, low alkalinity waters frequently gives unsatisfactory color removal. To obviate this condition, other methods of providing alka-

[1]J. W. Kellogg, "Residual Aluminum in North Carolina Filtered Waters", Journal of the American Water Works Association, 23:92. 1931.

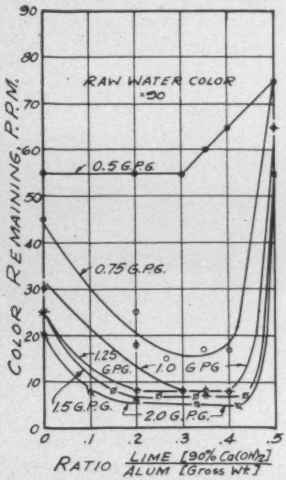

FIG. 1.—COLOR REMOVAL WITH ALUM & LIME.

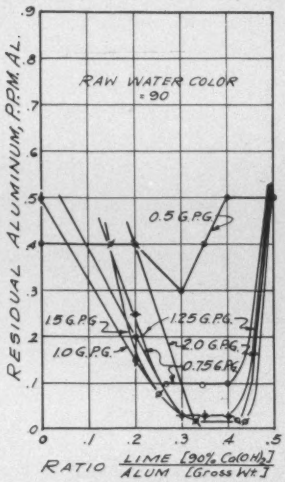

FIG. 2.—RESIDUAL ALUMINUM WITH ALUM & LIME.

linity have been used with a considerable degree of success at several water treatment plants. For example, at West Palm Beach, Fla.,[2] a water that is deficient in alkalinity during certain seasons of the year is conditioned for coagulation by adding a well water containing bicarbonate alkalinity. At the West Palm Beach Works, a plant-scale experiment using precipitated chalk gave equally good results but at a higher cost. It has been reported,[3] that the Bristol County Water Treatment Plant, Warren, R. I. has used commercial whiting successfully as a source of alkalinity. More recently, according to Mr. Flentje, this latter plant has been operated satisfactorily with ground limestone as a substitute for whiting.

With these experiences in mind, several series of tests were run on the Rancocas Creek water using precipitated chalk, whiting of two

[2]Pirnie, Malcolm, "Iron and Iron Coagulants", This Journal, 51:437, Dec. 1937.
[3]Flentje, Martin E., "Unusual Methods of Water Purification", This Journal, 43:38, March 1929.

different degrees of fineness, and ground limestone. The results obtained are particularly interesting because of the relationships between residual aluminum and the calcium carbonate-alum ratio. It will be seen from Figures 3 to 6, that excellent color removal is ob-

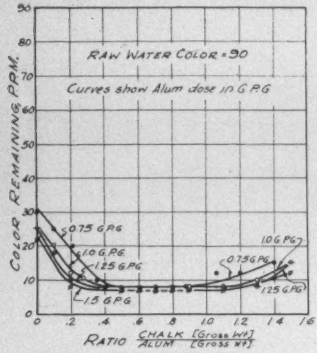

FIG. 3 — COLOR REMOVAL WITH ALUM & PRECIPITATED CHALK

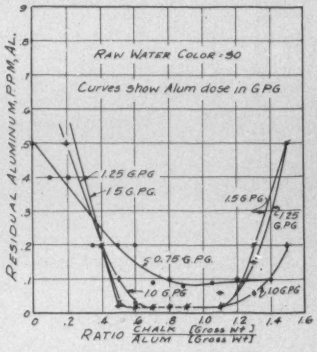

FIG. 4 — RESIDUAL ALUMINUM WITH ALUM & CHALK

tained with an extremely wide range in the calcium carbonate-alum ratio. The range of the ratio for low residual aluminum is not as broad as that for good color removal, but it is considerably higher than when hydrated lime is used. Figure 6 compares the various sources of calcium carbonate. It will be seen that the more coarsely ground the material, the larger is the quantity required for low residual aluminum. It would appear that the larger particles present in the coarser material are relatively ineffective as sources of alkalinity. This observation is substantiated by the visual observation that the coarser the material, the greater was the amount left undissolved in the bottom of the jar. Another interesting finding is that there is relatively little difference in total cost between cheap ground limestone in large quantities and expensive precipitated chalk in considerably smaller quantities.

It was intended to perform one more series of tests, but the demands of other work have so far interfered with its performance. Lime sludge from a softening plant might well be an acceptable substi-

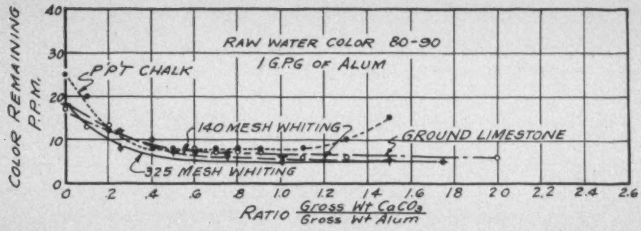

FIG. 5. – COLOR REMAINING WITH VARIOUS SOURCES OF CALCIUM CARBONATE

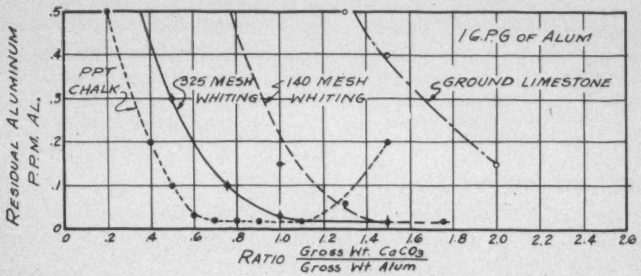

FIG. 6. – RESIDUAL ALUMINUM WITH VARIOUS SOURCES OF $CaCO_3$

tute for precipitated chalk if transportation difficulties could be overcome. For certain favorably located softening plants, a liability might become an asset.

Other Coagulants. Additional tests using other coagulants were performed. The data obtained will, for the most part, be touched on only briefly. Tests were run using alum and soda ash and alum and sodium aluminate. Both of these coagulating aids gave excellent color removal, but the residual aluminum was somewhat high. Ferric sulfate (Ferrisul), alone, with aeration, and with lime was tried, but high residual iron was found in the treated water. When precipitated chalk was used to provide alkalinity, much better results were obtained. When 15 p.p.m. or more of precipitated chalk were used with ferric sulfate, excellent results, both in respect to color removal and

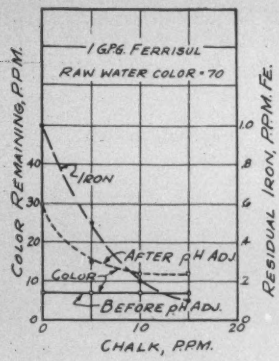

FIG. 7.—COLOR REMAINING AND RESIDUAL IRON WITH FERRISUL AND CHALK.

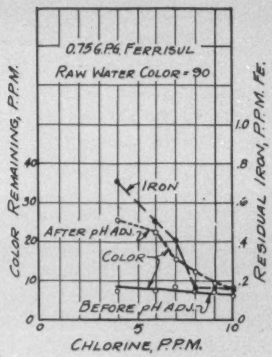

FIG. 8.—COLOR REMAINING AND RESIDUAL IRON WITH FERRISUL AND CHLORINE

low residual iron, were obtained (Figure 7). Chlorine with ferric sulfate was found to give good results when fairly large quantities were used. A minimum of 8 p.p.m. of chlorine added before the addition of 0.75 grain per gallon of ferric sulfate was required to produce the desired results (Figure 8).

Summary and Conclusions. This series of experiments demonstrates that for the water in question an end product low in color and low in residual coagulant can be obtained using alum and lime, alum and calcium carbonate, ferric sulfate and calcium carbonate or ferric sulfate and chlorine.

The ratio between the coagulant and the source of alkalinity, when alum is used, seems to be the significant relationship. The narrow limits between which good results are obtained when lime and alum are used makes this combination somewhat difficult to use in plant operation, particularly when small quantities of chemical are being measured by feeding devices that are not sufficiently precise in their delivery of chemical.

The use of precipitated chalk, whiting or ground limestone, in place of hydrated lime as a source of alkalinity, broadens the range considerably, but much larger quantities of the source of alkalinity

must then be used to insure low residual coagulant. Ferric iron in the form of ferric sulfate proved satisfactory when accompanied by alkalinity in the form of calcium carbonate or when high doses of chlorine were used.

It is not the purpose of this paper to discuss the economics of these several types of treatment, but a few generalized observations may not be out of place. A comparison of the costs of the different methods of treatment was made using values representative of those commonly encountered. No attempt was made to evaluate added labor costs brought about through the use of larger quantities of chemical or different processes. It was found that the lime-alum treatment was considerably lower in cost than any of the others. The cost of the calcium carbonate-alum treatment was only slightly greater, as measured by chemical costs alone, but from one and one-half to five times as much chemical would have to be handled. For this water, treatment with iron would be almost twice as costly as treatment with alum and lime.

The economy of the lime-alum treatment thus makes it desirable to exert considerable effort to obtain sufficiently precise feeding mechanisms to operate at the optimum lime-alum ratio.

RECENT DEVELOPMENTS IN THE USE OF HEXAMETAPHOSPHATE IN WATER TREATMENT

BY OWEN RICE*

[*Read September 23, 1941.*]

In a paper presented before this Association two years ago (1), the author reviewed briefly some laboratory experiments dealing with the action of small amounts of sodium hexametaphosphate in preventing the precipitation of calcium carbonate and in decreasing the corrosion of steel wool. At that time, this treatment had been quite thoroughly tested for its effectiveness in preventing the precipitation of calcium carbonate both in municipal and industrial plants, but only a few plants had actually started the use of metaphosphate for corrosion control. Consequently, although our laboratory tests had been quite thorough and the results most convincing, the author was somewhat reticent in his statements as to the results that could be expected in practice. Since that time, the adoption of this treatment has been quite rapid so that there are, at the present time, several hundred plants using sodium hexametaphosphate for corrosion control. Excellent results have been obtained in every one of these plants using water of widely varying characteristics, and the author is pleased to have this opportunity of presenting the additional information now available on corrosion control and on preventing the precipitation of dissolved iron.

The results obtained in several plants will be outlined briefly, but before doing so the results of our laboratory experiments made with steel wool will be summarized (2) because a consideration of these data should aid the understanding of the recommendations to be made and the results obtained in plant practice. These experiments showed the following:

1. Corrosion, as measured by the loss in oxygen content as the water passed through the bed of steel wool, decreased as the concentration of metaphosphate in the water increased.

2. In untreated water, an increase in the quantity of flow in-

*Calgon, Inc., Pittsburgh, Pa.

creased the total corrosion taking place. In water treated with metaphosphate, on the other hand, corrosion was decreased upon increasing the rate of flow. This indicated that the increased quantity of metaphosphate supplied to the surface at higher rates of flow formed a protective film at a rate that more than offset the effect of the increased supply of oxygen.

3. While the steel wool rusted too rapidly for effective protection to be given with a feed of only 0.5 p.p.m., it was found that if an initial protective film was formed with a higher rate of feed it could be maintained with a feed of only 0.5 p.p.m.

4. The effect of a heavily rusted surface was to increase the quantity of metaphosphate required to attain a given level of protection. This is due to the much larger surface area of the rusted surface as compared with a fresh metallic one.

5. The protective film formed on the surface with metaphosphate reduced corrosion at all pH values above 3.5 but best results were obtained at pH values above 5.0.

From these data it appears that the inhibition of corrosion by hexametaphosphate is the result of the adsorption of a thin film of this substance upon the surface of the metal. This is borne out by the fact that the rate of inhibition is dependent upon the rate of supply of hexametaphosphate to the surface rather than its concentration in the water. It was also noticed that when couples of black-iron, copper, lead, and brass pipes were being used in the laboratory for qualitative tests, interference colors developed on the surface, indicating that some sort of film had been formed. Qualitative tests indicate that this is an iron phosphate.

Preventing the Precipitation of Dissolved Iron

One of the newer and more interesting developments is the discovery that the addition of small amounts of metaphosphate to water will not only inhibit the corrosion of iron but will also prevent the precipitation of dissolved iron from well water. Such waters containing appreciable quantities of dissolved iron are usually devoid of oxygen. Upon reaching the surface, there is generally an opportunity for oxygen to be absorbed, either through the entrance of air into the suction of the pump or through exposure in standpipes, causing the precipitation of the iron with consequent discoloration and "red

water". It has been found that the addition of a minimum of 1 p.p.m. of sodium hexametaphosphate for each p.p.m. of iron (as Fe), if added to the water before chlorination or before the water has an opportunity to absorb oxygen, will prevent the precipitation of dissolved iron. Upon prolonged standing in contact with the air, the water will acquire a yellow color proportional to the iron content, but this is almost unnoticeable below 2 p.p.m. and so slight as to be unobjectionable when the iron content is below 5 p.p.m. Even this discoloration can be prevented by the addition of metaphosphate in an amount equal to four times the amount of iron present, the water then remaining clear and water white.

Approximately 20 industrial and 20 municipal water plants are using metaphosphate for preventing the precipitation of dissolved iron. In every case, the plugging of equipment or trouble with shots of "red water" has been eliminated. Where iron bacteria were present, it was also necessary to chlorinate, but here the metaphosphate was particularly valuable, because it prevented the precipitation of the iron by the chlorine. Some of these cases will be discussed later, but two points of considerable theoretical importance regarding this use of metaphosphate should be mentioned at this time.

1. We believe that the results observed are due to adsorption just as are the similar results in reducing the corrosion of metallic iron. Thus, if only 3 p.p.m. of metaphosphate are added to a water containing 5 p.p.m. of iron, the precipitation of the iron oxide may be delayed but not prevented. If, then, the supernatant water is tested for metaphosphate, it will usually be found to contain less than 0.1 p.p.m. On the other hand, if the precipitate is redissolved in acid and the solution is tested, all of the metaphosphate originally added to the water will be found. Hence, the metaphosphate must have been adsorbed on the precipitate and carried down with it.

2. We have not yet ascertained whether this action of metaphosphate is due to preventing the oxidation of the ferrous iron or simply to preventing the agglomeration and precipitation of the hydrated ferric oxide. We have some evidence to support both views but, at the present time, we are most interested in the results which show that, in any case, the iron stays in the water and no longer causes trouble even when present in quantities as high as 12 p.p.m.

Field Results

At the present time metaphosphate treatment for corrosion control is being used in 8 plants in Massachusetts, 2 in Rhode Island, 2 in Connecticut, and 29 in New York. I shall not bother you with long tables of data showing the results obtained at these plants but shall mention briefly the principal characteristics of the water in several cases, the feed of metaphosphate used, and the results reported.

Fairhaven, Massachusetts. A paper by Gidley & Weston (3) describes quite completely the results obtained with metaphosphate at Fairhaven. I understand that there has been no change in conditions during the past year and that "red water" is now unknown in this distribution system. It should be mentioned that the initial disturbance of old deposits which was pronounced at Fairhaven is a rather unusual occurrence. It has been noticed only where the raw water contains dissolved iron that has been precipitated in the distribution system as a non-adherent floc and never in connection with tubercles resulting from corrosion. In the paper (3) just referred to, it was pointed out that there was no tuberculation in the mains and that the original tar coating was intact. Thus, the deposits in the lines at Fairhaven were not tubercles formed by corrosion of the mains themselves. No softening of old corrosion products has been reported from any of the plants using metaphosphate for corrosion control, but a dispersion of old deposits has been reported from each of the plants where this treatment is being used to prevent the precipitation of dissolved iron from well water.

Winchester, Mass. The water at Winchester has a hardness of about 20 p.p.m., an alkalinity of 16 p.p.m., and a pH of 6.0 to 7.0. An initial feed of 10 p.p.m. of metaphosphate was used which was reduced to 2 p.p.m. one week later when some metaphosphate was being found in each of the dead ends. This initial treatment covered only a part of the system. The results obtained were so satisfactory that a feed of 2 p.p.m. to the entire water supply was started on March 10, 1941. Tests indicated that the pickup in dissolved iron between the reservoir and the extremities of the system had been reduced to zero by April 10. The improvement in conditions in this system through the metaphosphate treatment was greatly accelerated by the thorough flushing of all the mains. This not only increased the flow of water through the mains but removed the loose deposits of iron

oxide that would otherwise have absorbed large quantities of metaphosphate.

Millbury, Mass. The properties of the water supply of the Massachusetts Water Company at Millbury, Mass., are almost exactly the same as those of Winchester, namely, a hardness of 20 p.p.m., an alkalinity of 16 p.p.m., and a pH of 6.0. Tests made before the use of metaphosphate showed an increase in iron of 5 p.p.m. between the pumping station and some of the residences near the ends of the system. The feed of metaphosphate was started at 10 p.p.m. on February 19 and continued at this level through February 28. It was reduced to 2 p.p.m. on March 1 and has since been held at this value. By the middle of March, the pickup in iron had decreased to 0.3 p.p.m., and by the end of April, the pickup in iron was less than 0.1 p.p.m. It goes without saying that complaints had been eliminated.

Quite an interesting observation was made at one of the houses used as a sampling point in this city. This house was situated on one of the extremities of the system and was served with water through a 100-ft. section of 2-in. cast-iron pipe. Prior to the use of metaphosphate, it was noticed that the water taken at this point contained a black deposit. Several weeks after the treatment was started, this had turned brown. Soon thereafter, it was eliminated entirely. It is the author's opinion that the corrosion in this system was originally so severe that all of the oxygen had been depleted and black magnetic iron oxide was originally present in samples at this residence. As the metaphosphate coating progressively protected the surface, more and more oxygen remained in the water at this point and the iron was oxidized to the familiar red form. As treatment continued, the protective film was finally formed on the individual line leading to the residence and in the pipes of the house itself and finally little or no iron remained in the water and, hence, no precipitate or discoloration occurred.

Garden City, Long Island. Rogers (4) has reported on the preliminary results obtained with metaphosphate in the treatment of the water of Garden City, L. I. and later reports from him have confirmed the earlier ones. The pickup in iron between the pumping station and the extremities of the system has been reduced to zero, complaints and flushing of hydrants having been eliminated, and green and blue copper stains have also decreased. The water at Garden City is

very similar to that at Winchester and Millbury, the principal difference being that the pH is lower, namely, 4.9 to 5.6.

The low pH of the water at Garden City and at Fairhaven confirm the evidence previously secured in the laboratory anent the effectiveness of metaphosphate at pH values as low as 5.0.

Sumter, S. C. As humorously described by Ellis (5), Sumter, S. C., had long suffered periodically from a "wild water". This was occasioned by the necessity of turning in to the system at periods of high demand a well that contained 3.8 p.p.m. of iron. This water was "tamed" to quote Mr. Ellis, by adding 4 p.p.m. of metaphosphate to the water at the well. Thereafter, the water remained clear upon passing through the standpipe and distribution system. The results have been so pleasing that this well, treated with metaphosphate, has been kept in service for over a year now because it is the most economical to operate. Formerly it was used as little as possible.

Canton, O. At Canton, Ohio a condition existed that was similar to that at Sumter. The water from the southwest well contained 1.5 p.p.m. of iron that was precipitated in the distribution system following chlorination and passage through an open reservoir. This precipitate of iron oxide would then be dislodged at periods of high demand, especially on Monday mornings (of all times!) giving rise to many complaints. The addition of 3 p.p.m. of metaphosphate to the suction line of the deep well pump at this plant eliminated the "red water" troubles.

Jamaica, Long Island. At the Jamaica, L. I., plant of the Long Island Water Company, an average of 6 complaints of "red water" per day had been received in what is known as the Richmond Hill district over a period of several years. The iron content of the water from the 7 wells serving this district varied from 0.3 to 1.8 p.p.m. Metaphosphate was fed to each of these wells in an amount varying from 1 to 3 p.p.m., depending on the iron content. The system was thoroughly flushed in the first two weeks after treatment was started. During the year that has passed since then, only two complaints of "red water" have been received, and it is pertinent to note that both were from delinquent customers. Samples from various points in the system are checked and always found to contain the amount of iron calculated from the analysis of the wells that serve the section. The samples are left exposed to air for several days in the laboratory. If

they remain clear, the proper feed of metaphosphate is being maintained.

Tuberculation

The control of tuberculation is a further development in the use of metaphosphate. One might say that so far the "customer relation" of the problem has been discussed and that now the economic side of corrosion control is to be described.

From the very beginning of our first experimental work on corrosion, when some rough qualitative tests were being made on pipe, it was noticed that the presence of small amounts of metaphosphate notably reduced the rate of pitting and tuberculation. Further tests showed that this effect was obtained over the entire pH range as might be expected from the tests with steel wool. Even in these first experiments, however. it was noted that, with an increase in pH, there was an increased tendency to form tubercles whether metaphosphate was present or not. In other words, at low pH values the corrosion taking place was general in nature and fairly uniform over the entire surface of the pipe. As the pH was increased, corrosion became more and more localized and resulted in the formation of fewer but larger individual tubercles. In the presence of metaphosphate, exactly the same effect was noticed, the only difference being that the tubercles were smaller in number and size, darker in color, seemingly harder, and more dense.

During the past several years, this particular aspect of corrosion has been investigated rather extensively in our laboratory, using the experimental set-up shown in Figure 1. In these experiments, ¼-in. black-iron pipe was used, and no attempt was made to treat the interior surface before the test was started. Fairly consistent initial head readings and increases in the head were obtained on many duplicate runs, and we are convinced that the interior of the pipe was sufficiently uniform to make preliminary pickling or other treatment unnecessary. In the first two series of experiments, which are shown in Figures 2 and 3, 40-ft. lengths of pipe were used. In subsequent experiments, where higher rates of flow were used, the initial heads and increases in head were too large for the space at our disposal, and it was necessary to reduce the length of pipe.

Figure 2 shows the effect of increasing concentrations of meta-

USE BLACK IRON PIPE

IN ORDER TO DEMONSTRATE THE RESULTS OBTAINABLE IN ACTUAL USE, THE VELOCITY OF FLOW SHOULD APPROXIMATE THAT IN THE MAINS.

MINIMUM RECOMMENDED FLOWS FOR PIPE OF VARIOUS SIZES

PIPE SIZE	FLOW	VELOCITY FT./SEC.	LENGTH OF PIPE	INITIAL HEAD
1/4"	1.0 G.P.M.	3.08	10'	2.8'
1/4"	1.5 G.P.M.	4.60	10'	6.0'
1/2"	3.0 G.P.M.	3.16	10'	1.6'
1/2"	5.0 G.P.M.	5.20	10'	4.1'

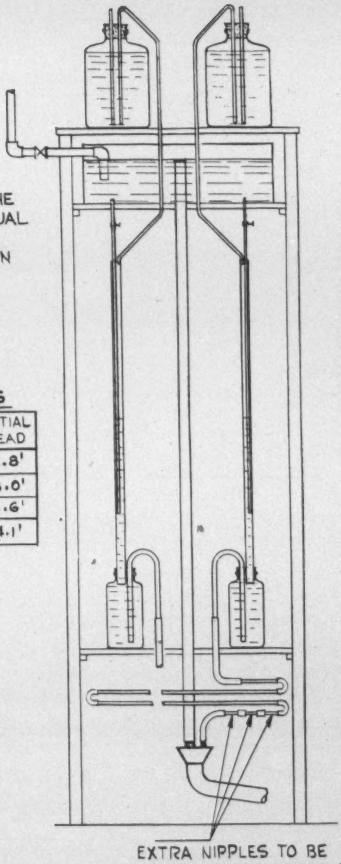

FIG. 1—EXPERIMENTAL TEST SET-UP USED TO DETERMINE EFFECT OF SODIUM HEXAMETAPHOSPHATE TREATMENT ON TUBERCULATION OF IRON PIPE.

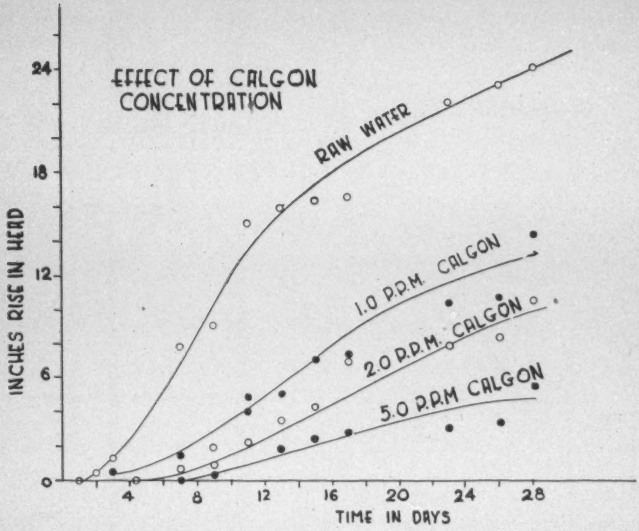

FIG. 2—EFFECT OF INCREASING CONCENTRATIONS OF HEXAMETAPHOSPHATE IN REDUCING TUBERCULATION AS MEASURED BY THE INCREASE IN HEAD OBSERVED WITH A CONSTANT FLOW OF 0.5 G.P.M. THROUGH 40 FT. OF ¼-IN. BLACK-IRON PIPE.

phosphate on the tuberculation of 40 ft. of ¼-in. black-iron pipe through which flowed Pittsburgh city water, the characteristics of which are recorded in the accompanying table. Figure 2 does not require any explanation, since it is apparent that, at a flow of 0.5 g.p.m., a feed of 1 p.p.m. of metaphosphate reduced the tuberculation 50 per cent as measured by the increase in head; while a feed of 5 p.p.m. effected a reduction of 80 per cent.

AVERAGE ANALYSIS OF PITTSBURGH CITY WATER DURING TEST

Bicarbonate (HCO_3)	8 p.p.m.
Chloride (Cl)	28 p.p.m.
Calcium (Ca)	29 p.p.m.
Magnesium (Mg)	4 p.p.m.
Total Hardness (as $CaCO_3$)	87 p.p.m.
Sulphate	130 p.p.m.
Suspended Solids (estimated)	1 p.p.m.
Total Dissolved Solids	263 p.p.m.
pH Value	5.6

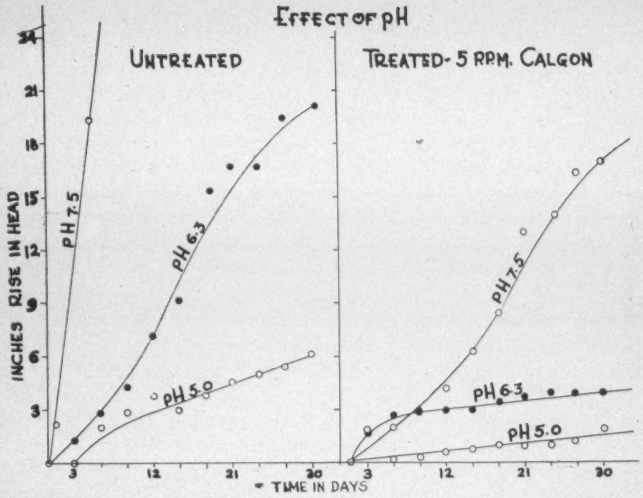

FIG. 3—EFFECT OF CHANGING THE pH UPON TUBERCULATION BOTH WITH AND WITHOUT ADDITION OF HEXAMETAPHOSPHATE. FLOW OF 0.5 G.P.M. AND 40 FT. OF ¼-IN. BLACK-IRON PIPE WERE USED IN THIS RUN.

Figure 3 shows the effect of variations in pH, both with and without metaphosphate, on the rate of tuberculation. Here, the tap water had a pH of 6.3, the other characteristics being similar to those of the previous run. The pH was lowered by adding a small amount of hydrochloric acid and raised in other instances by the addition of small quantities of soda ash. It will be noted that these curves show clearly the greater rate of tuberculation with increasing pH values.

In Figure 4 is shown the effect of increasing rates of flow on the effectiveness of corrosion control with a constant dosage of metaphosphate. Because of the head limitations previously mentioned, only 1 ft. of pipe was used in two runs at 1.5 g.p.m.; 10 ft. of pipe at 1 g.p.m.; and 40 ft. at 0.5 and 0.25 g.p.m. However, in the curve, the heads have all been adjusted to equivalent 10-ft. lengths of pipe. It is notable that much less tuberculation took place in the presence of 1 p.p.m. of metaphosphate at the higher rates of flow, for a greater in-

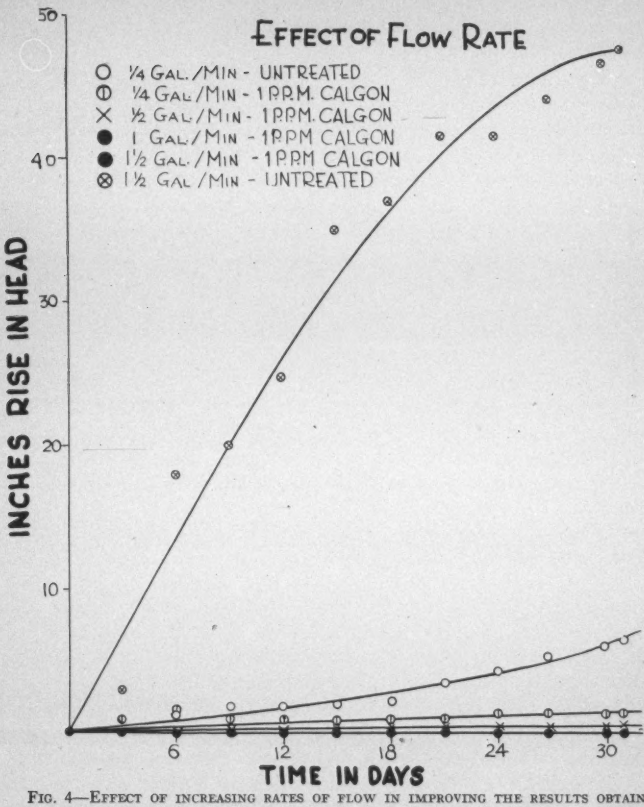

FIG. 4—EFFECT OF INCREASING RATES OF FLOW IN IMPROVING THE RESULTS OBTAINED WITH A LOW FEED OF HEXAMETAPHOSPHATE. SHORTER LENGTHS OF PIPE USED AT HIGHER FLOW RATES, BUT ALL HEAD MEASUREMENTS HAVE BEEN ADJUSTED TO THOSE EQUIVALENT TO A 10-FT. LENGTH OF ¼-IN. BLACK-IRON PIPE. AVERAGE pH OF WATER DURING TEST WAS 6.0.

crease in head occurred at a rate of 0.25 g.p.m. than at 1 or 1.5 g.p.m. This is just the opposite of the results obtained with untreated water and is due, we believe, to the increased turbulence at the higher

velocities which brings the metaphosphate into more intimate contact with the surface and so enhances film formation.

These experiments all tended to confirm the original inferences drawn from earlier experiments on pipe and steel wool. These were that best results in the reduction of tuberculation would be obtained at high rates of flow and low pH values. The velocities necessary to produce the slight turbulence required are not excessive and are, in fact, well within the limits used in designing distribution systems. It should also be pointed out again that the lower pH values are entirely practicable because it has been clearly shown, both in the laboratory and in the field, that metaphosphate will prevent "red water" even at a pH of 5.2.

Metaphosphate is a material that will reduce corrosion at low as well as at high pH values, and it has been shown that a reduction in tuberculation is obtained over the same wide range. It behooves us, therefore, to take advantage of the natural characteristic of iron to remain in solution at low pH values and to rely on the protective film formed by the metaphosphate itself to prevent too much iron going into solution, if we are to obtain the optimum results in reducing tuberculation.

In the paper presented two years ago (1), the author mentioned that a protective film was formed on lead as well as on ferrous metals. Full information on this effect has been published by G. B. Hatch (5). While a small amount of metaphosphate exerts a very pronounced protective action on lead, particularly at low pH values, Hatch shows that a slight increase in pH is more effective in preventing the solution of lead. Hence, in a plumbo-solvent water, where a large number of lead services are in use, it may be desirable to add sufficient alkali to increase the pH to about 6.0, even though this would be undesirable from the standpoint of tuberculation alone. If only a few lead services are in use, consideration should be given to their replacement.

Conclusion

The laboratory tests on both steel wool and black-iron pipe show that a reduction of corrosion is obtained by the use of metaphosphate due to the formation of a protective film on the surface of the metal by the adsorbtion of the metaphosphate from solution. One might say that we are not treating the water but are treating the metallic

surface. Also, because of this factor, the results obtained will be proportional to the actual quantity of metaphosphate passing over a given area of surface each day rather than to the concentration of metaphosphate in the water. Similarly, because with increasing velocities of flow more turbulence will result and a more intimate contact of the water with the walls of the pipe will take place, better results are obtained with low metaphosphate concentrations at high rates of flow.

The same factor is evident in the results obtained in municipal works. In almost every case, the values for dissolved iron and the amount of "red water" experienced drop as soon as some metaphosphate reaches the extremities of the system. A high initial feed is necessary, therefore, if some metaphosphate is to be maintained throughout the system soon after the feed is begun. Consideration of this characteristic, leads to the belief that best results in reducing tuberculation will be obtained on the transmission mains which are usually designed to carry water at velocities in line with those used in the experiments. Somewhat poorer results will be obtained in the distribution grid proper. It is easy to visualize dead ends where so little water is used in a day that it will be difficult with very low feeds of metaphosphate to eliminate entirely "red water". This condition can be greatly helped by installing a bleeder to carry more water through the line. It is obvious that it is more economical for the water department to clean up such conditions by wasting a few thousand gallons of water each day and thus to double the supply of metaphosphate to such a dead end than it is to double the dose of metaphosphate applied to the whole water supply. This practice has proved to be successful in several cities; although bleeding even larger quantities of water before the use of metaphosphate had not improved conditions.

One apparent contradiction implicit in the data should be mentioned. It is that one might suppose, because of the extensiveness of the distribution system, that a much larger feed of metaphosphate would be required in a large city than in a small one. This is true if the measurement is made in pounds per day, but if the figures are expressed in p.p.m., the reverse is true. Why this should be so, is clear when consideration is given to the size of pipe used in the distribution system and the relation between the surface area exposed and the number of gallons of water pumped each day. From such figures,

it is apparent that this ratio is much higher for small cities that have a relatively large percentage of 2-, 4-, and 6-in. mains than in the larger ones where much of the system is composed of 8-, 16-, and 30-in. lines.

From experience in corrosion control to date, the author would say that the minimum feed of metaphosphate required for the elimination of "red water" is roughly as follows:

Volume of Water	*Concentration of Metaphosphate*
Over 10 m.g.d.	0.5 to 1 p.p.m.
1 to 10 m.g.d.	1 p.p.m.
0.5 to 1 m.g.d.	2 p.p.m.
Less than 0.5 m.g.d.	4 p.p.m.

These figures are only very rough averages and are subject to almost infinite change depending upon the density of the distribution system and many other factors. A relatively high feed is recommended at the start, at least double that in the list, followed by reduced amounts of metaphosphate as some shows up at the extremities of the system. A minimum of from 0.2 to 0.5 p.p.m. should be maintained at all points. These estimates are based on observations on the control of corrosion and "red water". A higher feed will be found desirable where optimum results in reducing tuberculation are desired.

The action of a few parts per million of metaphosphate in preventing the precipitation of dissolved iron is particularly valuable in cases, such as that at Fairhaven, where the water from some of the wells in the system contain iron while that from others contains a small amount of oxygen. Here, both corrosion and the precipitation of the dissolved iron will occur simultaneously and the resulting "red water" conditions would be intensified rather than helped by the addition of an alkali. Similarly, little could be done to improve the quality of the water where only a small amount of iron was present. If the water contained less than 1 p.p.m. of iron, the installation of aeration and filtration plants, while affording a slight improvement in the quality of the water near the plant, frequently has resulted in little improvement in the outlying stretches of the system due to the fact that the increased oxygen content of the water caused enough

corrosion in the distribution system so that about the same amount of "red water" and dissolved iron were present as before. While 0.3 p.p.m. has been generally accepted as the figure below which dissolved iron will not cause any trouble, it is notable that Fairhaven is not the only plant which experienced "red water" due to the precipitation of such a small quantity of iron in the distribution system which was then picked up at intervals to cause a severe, though intermittent, "red water" condition. In such cases, treatment with metaphosphate offers an especially simple, easy, and economical remedy for what would otherwise be an unsolvable problem.

Finally, the author is convinced that metaphosphate will be found fully as effective in reducing the rate of tuberculation as it has been in controlling corrosion and "red water" in general. Only a few preliminary tests have been made on tuberculation in the field, but these have been in accord with our laboratory results, and the author feels quite confident in his conclusion that, while any pH may be used with equal success for controlling "red water", best results in the reduction of tuberculation will be obtained at relatively low pH values, i.e., below 7.0, and relatively high feeds of metaphosphate, i.e., above 2 p.p.m.

The reasons for applying small amounts of metaphosphate in the treatment of public water supplies may be summarized as follows:

1. To prevent the precipitation of calcium carbonate from both natural and softened waters.
2. To prevent "red water" due to the precipitation of dissolved iron from well water after chlorination or exposure to air.
3. To prevent "red water" due to corrosion encountered in natural or treated waters.
4. To reduce tuberculation.

References

1. Journal of New England Water Works Association, **54**, 1940.
2. Industrial & Engineering Chemistry, vol. 32, p. 1572 (December 1940)
3. Journal of American Water Works Association, **32**, 1484 (1940).
4. Journal of American Water Works Association, **32**, 1498 (1940).
5. Journal of American Water Works Assoc., **33**, no. 7, p. 1179, 1941.

Discussion

Edward W. Moore*. If someone had stood before this Association ten years ago, and stated that there existed substances which, in quantities as low as one or two parts per million, would mitigate the corrosiveness of a water without affecting its hardness, alkalinity, carbon dioxide content or pH to an appreciable extent, he would have been regarded as somewhat unreliable. Although some authorities remain as yet unconvinced, there is accumulating a mass of evidence that indicates that such substances do exist and that among them the meta- and pyro-phosphates are particularly successful. They have been used to eliminate red-water and tuberculation troubles where other means have failed, and if they have also failed in some instances, it must be remembered this is also true of all other methods of anti-corrosion treatment.

Just as with any new technique, certain special problems have arisen in the application of the phosphates to water treatment, and it is these problems that I wish to discuss.

A few water supplies that have introduced metaphosphate treatment have been disturbed by sloughing of old deposits within the pipes, with resulting black- or red-water troubles. Such difficulties have been rare, considering the number of supplies in which metaphosphate treatment has been started. Moreover, they seem to have been confined to supplies in which manganese or iron present in the water had been laid down as a deposit on the interior of the pipes. No such difficulties seem to have been encountered when the pipe incrustations were due to corrosion. So far, no remedy has been offered, except the heroic one of treating and flushing until the trouble disappears. This presumably occurs when all sloughable deposits have been eliminated from the system. The citizens have to put up with a few days of dirty water, but they may be mollified by the assurance that things will be much better after the system has been cleaned out.

The other problem relates to deductions drawn from the use of metaphosphate solutions for removing spray residues from fruit. It was reasoned that, if metaphosphates could disperse or dissolve lead arsenate, they might disperse or dissolve other lead compounds from

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the interior of old lead pipes, with unfortunate results for the consumer. Even with due allowance for the fact that the spray-residue-removing solutions are many times stronger than anything that would be encountered in water treatment, the matter is not one to be dismissed with a wave of the hand. Experiments by Fairhall, showing that 10,000 p.p.m. of metaphosphate increased the solubility of lead compounds tended to confirm suspicions.

The proof of the pudding lies in the eating thereof, and what is really needed to decide the point, is a series of analyses of water delivered from lead pipes or services, both standing and flowing, *before* and *after* the introduction of metaphosphate treatment. Up to the time of writing this discussion, such a detailed study has not been available. (Some data from the city of Fairhaven *after* the introduction of metaphosphate treatment are in the possession of the Massachusetts State Department of Health.) In the absence of information of this kind, recourse must be had to laboratory studies, and here it is more difficult to interpret the practical significance of the results.

Some laboratory studies have been made, or are in progress. Hatch (7) has shown that hexametaphosphates minimize the corrosion of fresh metallic lead, but the real problem is not the corrosion of the lead itself, but the redispersion or solution of deposits of basic carbonate or other lead salts present in old pipes. A parallel experiment by the writer, using Cambridge tap water, gave results opposed to those of Hatch, possibly because of the use of a different technique in cleaning the lead wool used, resulting in a different condition at the surface. The solution of this problem is particularly difficult, since one cannot be sure of reproducing, in the laboratory, the exact physical and chemical makeup of the interior lead deposits.

A number of experiments have been performed in the author's laboratory, and although the information is as yet insufficient for definite conclusions, the techniques and general nature of the results may be outlined as follows:

1. Experiments on the solubility of powdered basic lead carbonate in water with and without metaphosphate. The bulk of the experiments indicated an increase in the solubility, but the results are erratic and difficult to interpret in terms of practical significance.

2. Steady-flow experiments on lead wool (as mentioned before).

This wool was treated in such a way as to produce an oxide coating on the surface. Water containing metaphosphate consistently picked up more lead than water with no metaphosphate. This may be of some practical significance.

3. Experiments on old lead pipes, removed from service. On 24-hour standing, water containing metaphosphate up to 16 p.p.m. showed no greater lead content than water with no metaphosphate. Results are somewhat erratic. The difficulty in interpretation lies in the fact that the lead deposits may have been altered in character by standing dry for considerable periods of time.

4. Tests on lead pipe, freshly corroded by the passage of water. These have not yet been completed.

In general, the experiments so far have shown nothing very alarming. Wherever an increase in lead pickup due to metaphosphate has been noted, this increase has seldom been greater than one hundred percent, even when the amount of lead picked up by the water with no metaphosphate has been small. On this basis, it would seem that no very serious danger exists in the application of metaphosphates to water systems containing lead pipes or services. This is, however, merely an opinion, subject to alteration in the light of further experimental data.

EDISTO RIVER, GOOSE CREEK TUNNEL AQUEDUCT, CHARLESTON, S. C.

BY J. E. GIBSON*

[*Read September 24, 1941.*]

Historical. Edisto River was first proposed as a water supply for the City of Charleston in 1853 in connection with a navigation project to connect the head waters of the Ashley River near Bacon's Bridge with the Edisto River at or near Givhans (see Figure 1). The cost proving beyond the ability of the city to finance, the project was abandoned.

The next record we have of the proposed use of the Edisto was in 1897 when the City of Charleston purchased approximately 1300 acres of land, located on each side of the river, at Givhans Ferry, and the late J. L. Ludlow of Winston-Salem, North Carolina, made an exhaustive report looking to the procuring of a supply of 5 m.g.d. of water. Mr. Ludlow's report included the building of a pumping station near Givhans Ferry Bridge with a 36-in. cast-iron discharge line from this pumping station to a point on Meeting Street Road, 5½ Mile, where a high-lift pumping station and filter plant were to be erected for delivery of water to the city proper. Here again, the project was beyond the ability of the city to finance, and negotiations were entered into with the then private company looking to a development of a new supply.

The private interests, representing the private company, interested the American Pipe and Construction Company of Philadelphia and the Mercantile Trust Company of Baltimore in the project, and the late J. W. Ledoux, Chief Engineer of the American Pipe and Construction Company, investigated the Edisto River supply and checked the findings of J. L. Ludlow. The cost of the Edisto project proving beyond the limits of finance, Mr. Ledoux proposed an impounded supply from Goose Creek, a tributary of Cooper River located about thirteen miles north of the city. This was a storage proposition with a normal yield of approximately 6½ m.g.d., with a minimum

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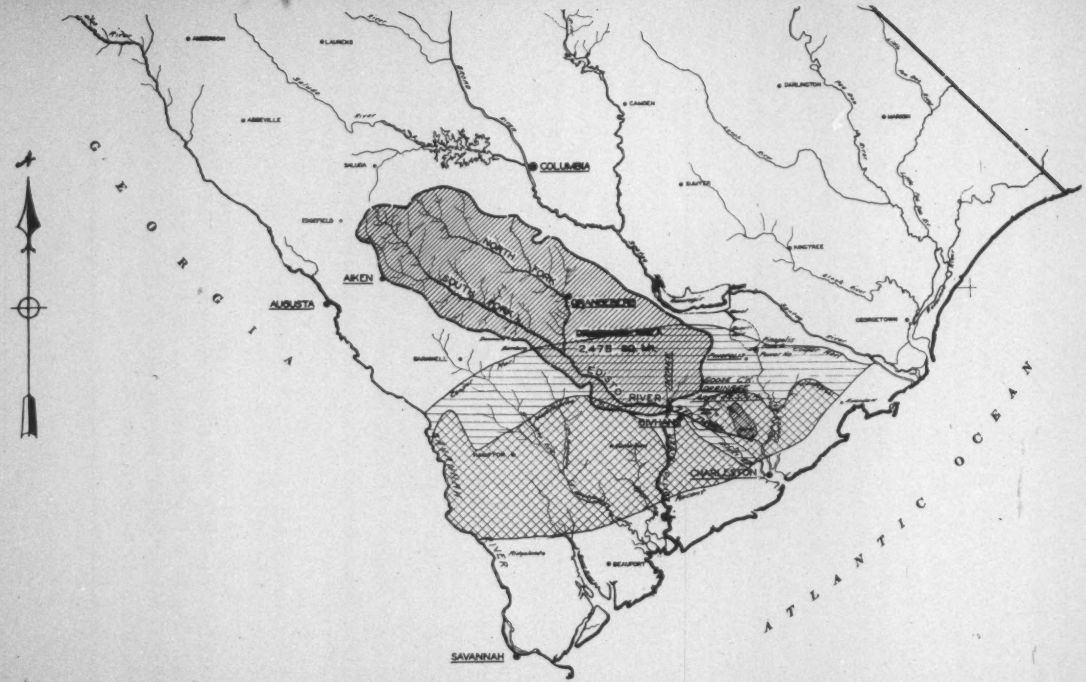

FIG. 1.—DRAINAGE AREA OF EDISTO RIVER.

yield during dry years of 5½ m.g.d. A new franchise was granted to the reorganized private company, based on a water supply to be taken from Goose Creek as proposed by Mr. Ledoux.

In 1916, a severe unprecedented rainfall of 19 in. in 24 consecutive hours overtopped the Goose Creek storage basin dam and washed it out, and the city was threatened with the loss of its entire stored water supply. The breach in the dam was repaired in time to save a portion of the stored water; however, due to a drought the storage basin did not fill, and in 1918, the city suffered from a shortage of water. The increasing demands of the city due to normal growth, and a second drought occurring in 1926 caused a second period of shortage of water. The city had in October, 1917, purchased the water plant of the private company and the writer was employed as manager and engineer.

Due to the recurring water shortages of 1918 and 1926, the department was authorized to make a report on all the available sources of water supply for Charleston, with the object of obtaining an adequate water supply to meet all reasonable requirements even under the most severe drought. After a most careful survey and study, the department recommended a supply from the Edisto River, to be taken at a point near Givhans Ferry Bridge and carried by a tunnel aqueduct to the Hanahan Pumping Station on Goose Creek. It was proposed that this tunnel aqueduct be built in sections as it became necessary and as rapidly as it was possible for the department and the city to finance.

In 1928, the first or Jahnz section of 4½ miles of tunnel aqueduct was planned and constructed by contract. This section diverted the water from the Edisto River into the upper drainage area of the Ashley River.

As a war measure in 1918, the department had constructed a dam across the Ashley River at Bacon's Bridge and installed an oil-engine-driven centrifugal pump to lift the water from the Ashley River over the divide, 26 ft. in elevation, into the Goose Creek storage reservoir; therefore, the proposition for the Edisto supply was to divert the water from the Edisto River into the upper head waters of the Ashley River, and let it flow down the river channel to Bacon's Bridge dam where it would be picked up by the Bacon's Bridge pumps and delivered into the Goose Creek storage basin. This method was used

during the drought period of 1931 for a period of about five months.

In the fall of 1935, I was invited by Malcolm Pirnie, of New York City, to attend a consultation in Covington, Virginia. At this conference, it developed that the West Virginia Pulp and Paper Company was considering a number of cities in the South for the establishment of a Kraft paper mill, and Charleston was one of these cities. The result of this conference and of later negotiations was that the West Virginia Pulp and Paper Company acquired a site on the Cooper River at what was then known as the Port Terminals in the North Charleston area, about nine miles from the center of the city of Charleston, and the Commissioners of Public Works of Charleston undertook to complete the remaining sections of the Edisto-Goose Creek Tunnel to take the water from the outfall shaft of the original section and carry it to the Hanahan Pumping Station and Goose Creek storage reservoir. Here they would turn the water over to the West Virginia Pulp and Paper Company to whom they had leased five acres of land for a pumping-station site. The West Virginia Pulp and Paper Company erected a pumping-station building and pumps to lift the water from the exit shaft of the tunnel through a 48-in. pipe line to their storage reservoir and mill at North Charleston—a distance of approximately 3½ miles.

This in brief is the historical background of the Edisto water supply of the city of Charleston.

Geological. The Edisto River-Goose Creek Tunnel aqueduct (Figures 2 and 3) is constructed entirely below mean sea level through what is known as the Cooper and Ashley River marl. This marl is a limestone formation of the tertiary period. In color it is a dark, drab, grayish white to a pea green. The marls of South Carolina occur in the cretaceous, eocene, oligocene, miocene, pliocene and pleistocene formations. The marl exposures occur principally along the Edisto, Ashley, Cooper, Santee, and Peedee rivers, and their tributaries of the coastal plain. The tunnel, however, is constructed entirely through the Cooper and Ashley River marl, of the late eocene and early miocene formations. Those who are interested in the geology of these marls are referred to a publication "Catalog of the Mineral Localities of South Carolina", by Earle Sloan, State Geologist, and to "Geology of the Coastal Plain of South Carolina", by C. W. Cooke, U. S. Geological Survey Bulletin 867, 1936.

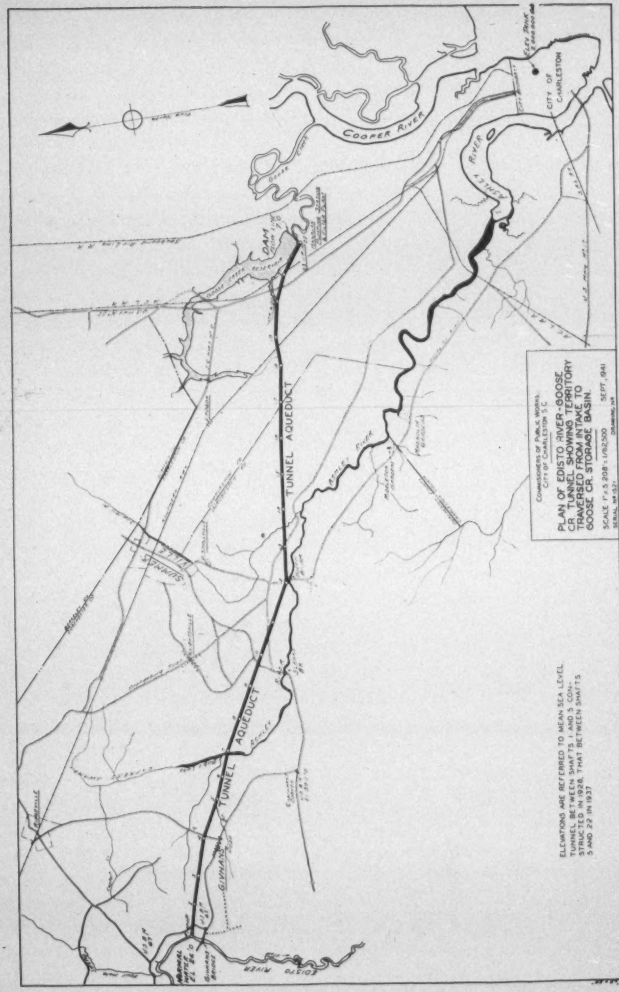
COOPER RIVER
CITY OF CHARLESTON
TUNNEL AQUEDUCT
TUNNEL AQUEDUCT
EDISTO RIVER
PLAN OF EDISTO RIVER-GOOSE CR. TUNNEL SHOWING TERRITORY TRIBUTARY FROM EDISTO TO GOOSE CR. STORAGE BASIN
ELEVATIONS ARE REFERRED TO MEAN SEA LEVEL
TUNNEL BETWEEN SHAFTS 1 AND 3 CONSTRUCTED IN 1936
SHAFTS 3 TO 5 THAT BETWEEN SHAFTS 3 AND 5 IN 1937

FIG. 2.—PLAN OF EDISTO RIVER-GOOSE CREEK TUNNEL.

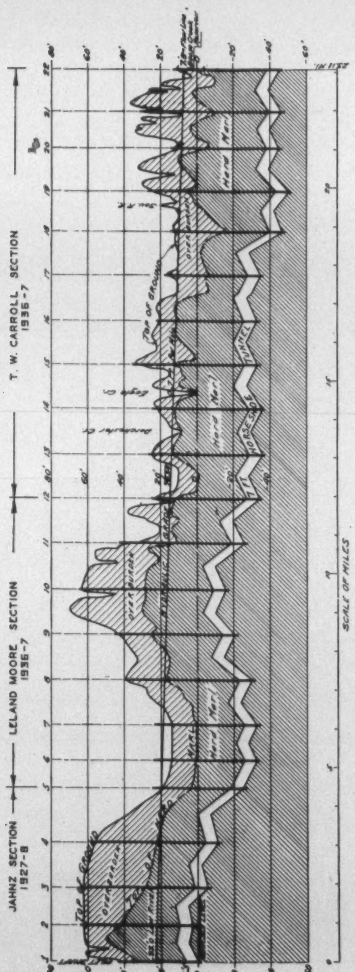

FIG. 3.—PROFILE OF EDISTO RIVER-GOOSE CREEK TUNNEL.

ANALYSES OF MARL SAMPLES FROM EDISTO-GOOSE CREEK TUNNEL

ITEMS	SHAFT 1 Apr. 27 1928 %	SHAFT 3 Apr. 25 1928 %	SHAFT 5 West Heading (15 ft. from shaft) Apr. 20, 1928 %	SHAFT 6 East Heading (1537 ft. from shaft) Nov. 23, 1936 %	SHAFT 6 West Heading (1515 ft. from shaft) Nov. 23, 1936 %	SHAFT 8 East Heading (670 ft. from shaft) Nov. 23, 1936 %	SHAFT 8 West Heading (670 ft. from shaft) Nov. 23, 1936 %	SHAFT 20 East Heading (750 ft. from shaft) Nov. 23, 1936 %	SHAFT 21 East Heading (700 ft. from shaft) Nov. 23, 1936 %	SHAFT 21 West Heading (650 ft. from shaft) Nov. 23, 1936 %	SHAFT 22 West Heading (1125 ft. from shaft) Nov. 23, 1936 %
Moisture (as received)	1.86	16.64	14.58	15.45	22.67	20.06	21.31	23.99	16.11	23.34	23.12
Silicon dioxide ($Si O_2$), sand, etc.	13.04	26.31	—	13.74	26.99	10.95	10.66	19.93	10.21	20.81	10.15
Iron and aluminum oxides ($Fe_2 O_3$ & $Al_2 O_3$)	1.78	4.27	—	0.96	1.99	0.69	0.81	2.02	1.25	1.13	1.61
Calcium oxide (Ca O)	46.62	26.88	—	39.32	37.79	47.12	47.26	41.89	46.00	38.86	45.46
Equivalent to calcium carbonate ($Ca CO_3$)	81.76	48.04	54.44	70.16	67.49	84.12	84.40	74.80	77.97	69.39	78.09
Magnesium oxide (Mg O)	Trace	Trace	—	0.70	1.02	0.94	0.69	0.76	0.58	1.23	0.77
Equivalent to magnesium carbonate ($Mg CO_3$)			—	1.46	2.13	1.96	1.44	1.39	1.21	2.57	1.60
Sulphur trioxide (SO_3)	Trace	Trace	—	0.06	0.10	0.09	0.09	0.10	0.20	0.16	0.28
Phoshorus pentoxide (P_2O_5)			—	0.58	0.68	0.56	0.66	1.15	3.42	1.35	3.46

Analyses of the Ashley and Cooper River marls, as shown by samples taken from the tunnel during construction, are given in detail in the accompanying table, all analyses being made by the Parker Laboratory of Charleston, S. C. It will be noted that the calcium oxide content of this marl varies from as low as 27 to as high as 47 per cent, and the equivalent calcium carbonate from as low as 48 to as high as 84 per cent. In a natural state, it is more or less plastic and can be easily cut with a sharp-edged tool; however, it becomes very hard upon exposure to the air.

At the instance of Mr. Pirnie, Consulting Engineer for the West Virginia Pulp and Paper Company, samples of this marl were taken and submitted to Charles P. Berkey, Emeritus Professor of Geology, Columbia University, for his examination and report. Fig. 4 is a photomicrograph prepared under Dr. Berkey's direction—magnification 30 diameters—and it clearly shows the micro-structure of this marl or rock. Dr. Berkey in his description says the following:

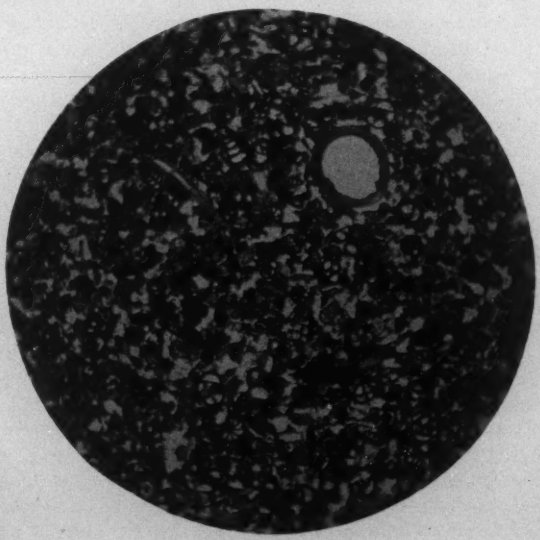

FIG. 4.—PHOTOMICROGRAPH OF MARL.

This photomicrograph . . . shows the micro-features. . . . In general make-up it consists principally of fossiliferous material (foraminifera) with finely broken material of the same origin partially filling the interstitial spaces.

It is not a very hard rock, however, for most of the material is from micro-shells. They were always frail and still are so. The individual shells are easily broken apart and can be crushed in the fingers. Undoubtedly this rock would not give a high strength test but it is strong enough to cover the ordinary purposes connected with such a project as this. The lack of lamination or bedding structures is favorable. It is well enough bound for the grains to hold together reasonably well unless subjected to abrading action.

Although the composition (chiefly calcium carbonate) yields slowly to solution by water, this action in such a rock would be fairly uniform. As a result, if water were taken directly from such a formation after seeping through its myriad pores, it would be hard; but the attendant destruction of the rock by solution would be slow and inappreciable except along joints and bedding planes.

The micro-structure of the rock is so fine, including the pore spaces, that it is not really pervious, although the rock has a large percentage of pore space. It absorbs water rapidly but does not yield it readily because of capillary control. Once filled up, therefore, it is fairly tight.

These conclusions of Dr. Berkey are borne out by actual observation and results, and during the construction of the tunnel the infiltration of water from the surface and through the rock was less than ½ g.p.d. per foot of length of the 7-ft. diameter tunnel of 22-ft. circumference.

Edisto River Drainage Basin. The Edisto River has its head waters in the central west portion of the state near Aiken. The stream flows in a generally southeasterly direction through the sandy alluvial formation to its mouth into the Atlantic Ocean in the southeastern section of the state near Beaufort. It is one of the few streams along the Atlantic Coast that is not turbid. The intake of the tunnel aqueduct near Givhans, S. C., is about 23 miles above tidal influence at the crossing of the Atlantic Coast Line Railroad near Jacksonboro.

The normal elevation of the river at our intake is 26 ft. above mean sea level and the minimum elevation taken at the time we located the intake was 23 ft. However, during the severe drought of last fall and this spring the level of the river did fall to 22.3 ft. above mean sea level.

The drainage area of the river at our intake is 2476 sq. miles, and the minimum average monthly flow of record, November 1939, 0.284 c.f.s. per sq. mile or 183,000 g.p.d. per sq. mile, or a total of

450 m.g.d. The minimum daily discharge has gone as low as 0.22 c.f.s. per sq. mile, or slightly over 140,000 g.p.d. per sq. mile, or a total of about 350 m.g.d. The capacity of the tunnel by gravity is 55 m.g.d. and if pumping is resorted to and the elevation of the water is lowered in the outlet shaft to elevation —13, 75 m.g.d. are available. It will be noted therefore that there is more than ample supply for the city of Charleston and environs for many years to come—the present consumption of the city proper being only 8 m.g.d. and the present maximum demands of the West Virginia Pulp and Paper Company for raw water being 30 m.g.d.

Construction of the Tunnel Aqueduct. The Edisto River-Goose Creek Tunnel aqueduct follows a southeasterly direction from the intake shaft near Givhans (Figure 5) to a point on the Ashley River at

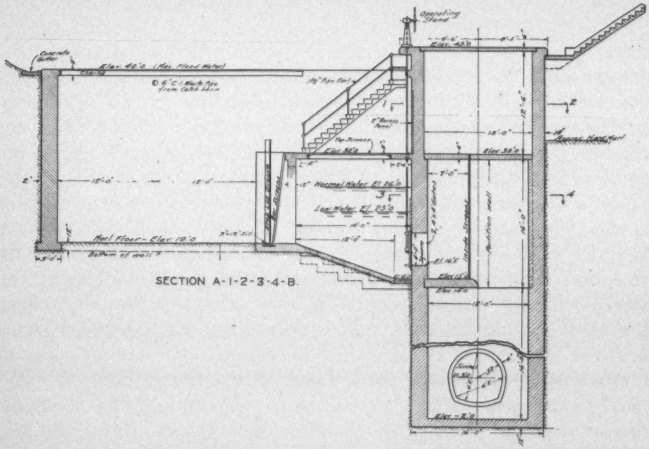

FIG. 5.—EDISTO RIVER INTAKE. FOREBAY AND SHAFT. GIVHANS, S. C.

Bacon's Bridge, where it deflects slightly to the north to Shaft No. 20, which is on an arm of the Goose Creek Reservoir; thence it passes in a more southeasterly direction to the terminal shaft No. 22, at the Hanahan Pumping Station and filter plant on Goose Creek. The total length of the tunnel is 23.11 miles from its intake shaft to the outlet

shaft No. 22. The first 4½ miles from intake shaft to No. 5 shaft were constructed in 1928, being finished in January, 1929. As heretofore mentioned, this portion of the tunnel was used during the year 1931 for a period of about five months. The tunnel from Shaft 5 to terminal shaft No. 22 at Hanahan Pumping Station—a little over 18½ miles in length—was constructed from July 1, 1936, to May 30, 1937, or in ten months.

Before actually closing the contract for a raw water supply for the West Virginia Pulp and Paper Company, the engineers of that company, Messrs. Pirnie and Sanborn, desired to make an inspection of the section of tunnel constructed in 1928. Accordingly, in the spring of 1936 the 4½ miles from intake shaft to Shaft No. 5 were unwatered, and an inspection was made on Saturday, April 18, 1936.

The inspection party consisted of Mr. Pirnie, Consulting Engineer, Mr. Paige, Consulting Geologist, U. S. Government, Mr. Carey, U. S. Engineer engaged on the Florida Ship Canal at Ocala, Florida; Mr. Burwell, State Geologist of Florida; Mr. Arenander of Mr. Pirnie's office; Mr. Sanborn, Consulting Engineer, New York City; Mr. Parker, Tunnel Expert of New York City; and the following men representing the Commission: F. B. McDowell, Jr., J. W. Thompson, J. S. Limehouse, William Wiggins, John Benke, C. G. Shipley, and myself. The party entered the outfall shaft on Dodds Branch and walked westward through the 4½ miles, making their exit at the inlet shaft at the Edisto River. The tunnel was found to be in most excellent condition, there being less than a half yard of material that had sloughed or slipped off in the entire 4½ miles. Tally marks at the shaft entrances were noted in several instances where the workmen had tallied the number of muck cars removed during the day. These tally marks were sharp and perfectly legible.

The engineers of the Commissioners of Public Works had previously prospected the territory lying between Goose Creek reservoir and Shaft 5 by collecting information on all known wells, marl pits and the outcrops of the marl at Bob's Lake and Bacon's Bridge, on the Ashley River, the marl pits at Ashley Phosphate, and outcrops of the marl at Goose Creek. While they were satisfied in their own minds as to the existence of marl throughout this section, before actually beginning the construction of the tunnel, wells were placed at each proposed shaft location and at intermediate points. These wells were

drilled by the ordinary well rig, 5 in. in diameter, iron casings being driven down until the marl was encountered, after which the boring went through the marl to a point usually some 40 ft. deep into the marl. Usually, a well was placed 300 to 500 ft. from each proposed shaft and a second set of two wells about 2500 ft. from each shaft. These wells were driven directly on the line of the tunnel and were later used to check alignment of the driven tunnel. Subsequently, and after completion of the tunnel, the wells were filled with concrete, a 2-in. pipe, however, being centered in them to act as a vent, and this pipe was brought to the surface of the ground with a U bend screwed on the top. The tunnel was so located as to have in all cases a minimum thickness of 20 ft. of hard marl above the intrados.

One of the provisions of the contract between the West Virginia Pulp and Paper Company and the Commission was that the water was to be delivered to the West Virginia's plant within a period of 12 months from July 1, 1936. After considering all phases of construction, the delay necessary to prepare adequate plans, period of advertisement, the investigation required by contractors to familiarize themselves with conditions, the subsequent period of investigation of the contractors and the closing of the contracts, all of which we felt would require not less than 90 days, and after taking into consideration the intimate knowledge which the engineers of the water department had of the territory, and the experience gained in the construction of the 4½ mile section in 1928, the Commissioners of Public Works decided to undertake the construction of the work themselves, and for this purpose employed Robert E. Parker, Tunnel Expert of New York City, as constructing superintendent on the job. F. B. McDowell, Assistant Manager and Engineer of the Water Department was in charge of the engineering, locations, etc., and the construction of the work generally was carried forward under the author's general management.

Accordingly, construction forces were organized by Mr. Parker, and we actually began the location and clearing of some of the shaft sites as early as June, 1936, anticipating the final closing of the contract on June 19, 1936. There were 17 shafts: No. 6 to 22 inclusive. The depth of the overburden on the marl at these various shafts varied from as little as 6 ft. to as high as 30 ft., and two methods of shaft sinking were employed. Where the overburden was less than

16 ft., the ordinary type of sheathing pit down to the marl was used, but where the overburden exceeded 16 ft., the caisson type of shaft sinking was adopted. As a rule, very little water was encountered in sinking these shafts until a point just above the marl was reached where usually sand and phosphate rock were encountered and considerable water. This water was troublesome to handle until the sheathing or caisson was well seated in the marl, after which the lining of the upper shaft could be constructed. Here we adopted what we considered a unique feature of construction. After the caisson section had reached the marl and entered it for a short distance, the marl was undercut for about 18 in. and then carried down a distance of from 3 to 5 ft.; necessary forms were provided and concrete was poured in this undercut section and joined with the concrete of the upper caisson section, after which no further trouble was encountered from water and the undercut section supported the upper concrete casing shaft (see Fig. 6). The marl was then excavated to the neat inside diameter of the upper concrete shaft section down to the desired depth of the tunnel where the headings were started in each direction, and the work was prosecuted without any further concrete work being done until the headings met, tunnel section trued, track and all material removed from tunnel proper, after which the section of the shaft was enlarged to provide for a 9-in lining of either concrete or brick. The reason for using brick in some cases was the inaccessibility of the shaft site and the difficulty of getting material to it; and the use of brick with cement mortar offered the least difficulty as to material to be hauled and required the minimum number of workmen in placing. As all of this brick work is below ground from 20 to 40 ft., and will be covered with water of nearly uniform temperature, it is believed that it will be just as enduring as any other material. Brick work in the locks of the old Santee Cooper Canal built about 1793-1800 is still intact and in perfect condition.

The alignment of the tunnel was carried down the shafts by means of heavy mercury plumbs supported on piano wire and floating in buckets of oil. The base line was about 9 ft. Usually, the engineering work of alignment was carried on during Sundays; daily check however was made as the work progressed. Then the 5-in. wells drilled to determine the elevation and depth of the marl afforded accurate checks after the tunnel had been driven some 300 ft. in each

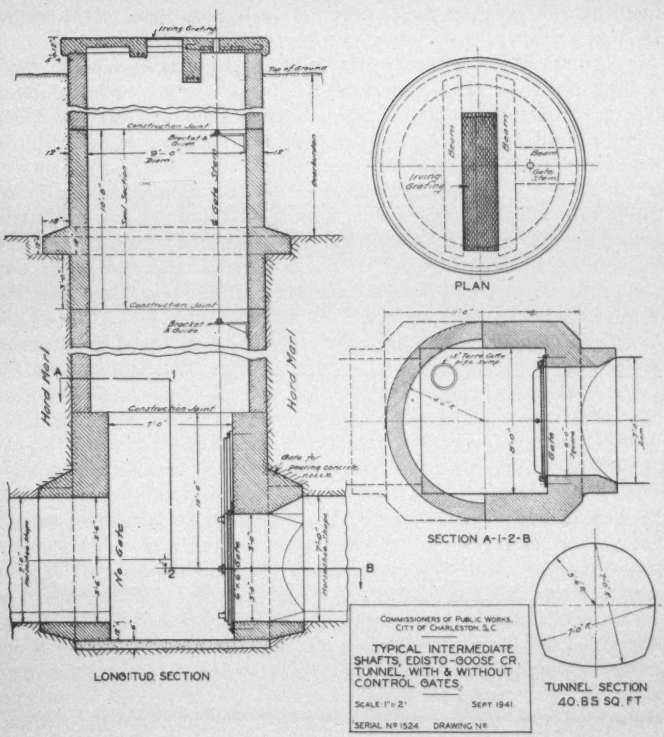

FIG. 6.—SHAFT WITH CONTROL GATE. EDISTO RIVER-GOOSE CREEK TUNNEL.

direction from the shaft, and a third check was had when the well 2500 ft. from the shaft was reached.

The shafts were usually placed about 6000 ft. apart, and there was a minimum ascending grade of approximately 0.2 of 1 per cent carried forward from the heading to the junction point in the middle between shafts. The purpose of this was twofold. First to afford drainage for any entrained water that might accumulate in the tunnel

and second to provide for a slight grade for the workmen to push the muck cars to the shaft for hoisting to the surface.

The muck cars were of 18½ and 24 cu. ft. capacity, and we used a light 20-lb. rail laid with iron cross-ties. Passing switches were placed, usually about 600 to 800 ft. apart, and all muck cars were equipped with Timken or Hyatt roller bearings. At each shaft there were installed an oil-engine-driven air compressor of 160 c.f.m. capacity, a 5 kilowatt gasoline-driven direct-current lighting plant, and a Ford V-8 industrial gasoline engine direct-connected to a United Hoisting Company's double reduction, single drum hoist. These were located to one side of the shaft with a head frame directly over the shaft. An elevator was installed in the shaft proper, the muck cars were pushed on to the elevator lift and hoisted to the surface and then carried to the spoil bank. There were in all 17 of these units. There were 7 Gardner-Denver caterpillar Diesel-driven compressors, 6 Ingersoll-Rand Type "H" engine-driven compressors, and 4 Ingersoll-Rand Type "CHK" gasoline-driven compressors. The oil-engine compressors were very satisfactory and have many advantages over gasoline-driven ones, particularly in the territory through which this tunnel was constructed, in that the quantity of fuel required is reduced to about ¼ and the loss by waste and theft is immaterial. The air and lighting circuits were carried down the shaft to one side, out of the way of the elevator, and thence along the sides of the tunnel to each heading. Installed at the foot of each shaft was a small Duplex pump usually 4½ in by 2¾ in. by 4 in., using compressed air as the motive power for pumping the entrained water from the tunnel to the surface. This pump was used only a few hours each day to remove the seepage water and condensation from the compressed air. As the tunnel progressed inward, it was of course necessary to use the pump more and more, but even when it was draining 6000 ft. of tunnel, it was not used more than 50 per cent of the total time.

Powder—60 per cent gelatin—was used to blast out the marl heading so that it could be handled with pneumatic spades and shovels. Usually there were five holes at each heading—four of them being placed around the circumference of the tunnel and about 15 in. from the finished face, with the fifth hole placed horizontally and immediately in the center of the tunnel heading. These holes were driven

by pneumatic drills, Gardner-Denver type, to a depth of 5 ft. One stick of gelatin was placed in each hole and lightly tamped, as it was found that, by light tamping, the marl was shattered more and the gases from the explosion reduced to a minimum, the marl seeming to absorb them.

Work was carried forward in two shifts of ten hours, the extra two hours on each shift being used for change of men, extending lighting circuits, track, and air compressor lines, etc.

A major portion of the work was done by task; that is, each crew was paid a fixed sum for a set quantity of work to be done; and for any additional work of prosecuting the headings over and above this set quantity, they were paid a prorated amount of the fixed sum. Under this program, the quantity of work set to be accomplished each week by each shift was 51 ft. of tunnel heading, or a total of 102 ft. for each heading. Nearly every week, the established quantity was exceeded, and in some weeks twice the work was accomplished that had been set as a unit During the week ending December 10, 1936, over 6098 ft. of heading were driven by the 66 shifts, or approximately 92.4 ft. per shift for the week.

The procedure was that each crew would fire an explosion just before knocking off on each shift, leaving this to be mucked up by the incoming shift. The incoming shift would then make a second explosion about three or four hours after coming on, clean this muck up, make a third explosion just about near the end of their shift, leaving this to be mucked up by the incoming second shift. However, many times they cleaned up the muck left by the last explosion of the preceding shift and made three explosions of their own, leaving the last or third one for the incoming shift. In other words the more nearly true average was 15 ft. of heading per day per shift. The heading crews were expected to trim the tunnel roughly to shape (see Fig. 7), leaving a margin of approximately 2 in. in the circumference to be dressed out by the finishing crews. This work however was left to the very last, after all headings were holed through, at which time the same crew that had been driving the heading was turned into a finishing crew. The alignment and finishing of the interior surface of the tunnel was done by hand, using pneumatic spades, and for the final trimming and finishing an ordinary carpenter adz with about 4½-in. blade with the curvature slightly increased so that starting

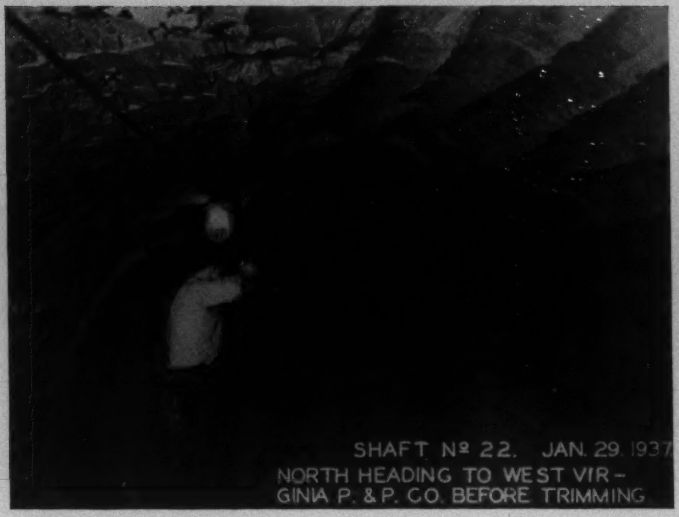

FIG. 7.—TUNNEL BEFORE TRIMMING.

at the top or intrados of the tunnel a man could trim downward on each side using a light wooden templet to get the true form and shape of the tunnel. The adz did not require sharpening except occasionally when some solid or hard marl was encountered, containing considerable quartz or sand in the matrix. Some of the rock was hard enough to strike sparks when hitting it with these edged tools, but this, occurring very rarely, was the exception and not the rule.

No ventilation was provided, the 5-in. well openings, heretofore referred to, offering considerable draft, and in some cases these openings were extended for several feet above ground to increase the draft. This with the discharge from the air drills and spades afforded all the ventilation required. The temperature in the tunnel remained practically normal, winter and summer; in fact, it was much more comfortable working in the tunnel than working on the surface, since it was cooler in summer and warmer in winter. Condensation and fog at times interfered with the engineering work in the tunnel.

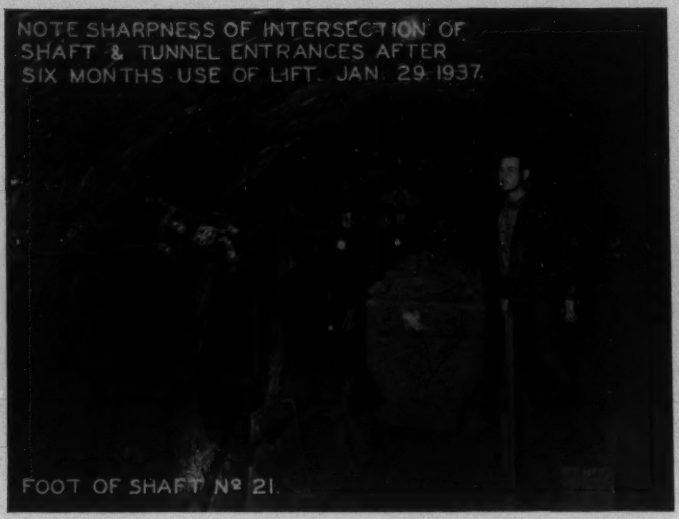

FIG. 8.—TUNNEL AFTER TRIMMING.

The tunnel is unlined throughout its length (see Fig. 8), and during construction there was no appearance or indication of earthquake cracks, faults, or slips in formation; in other words, it was 23.1 miles of almost uniform homogeneous material. The plasticity of the material at the east, or Goose Creek end, was slightly more evident, and the color changed from a dark drab gray to a pea green or blue. All shafts were lined with concrete from their base to the top and each shaft was provided with a sump so that in the future should unwatering be desired the suction pipe of the pumps could be placed in this sump.

Shaft No. 12, located on the bank of the Ashley River at Bacon's Bridge, is a special type. It is so arranged that the flow of water can be cut off by sluice gate. A gate valve in Shaft No. 7 on the bank of Bob's Lake can also be closed and the water diverted from Shaft No. 7 into the Ashley River to flow down the natural channel of the river and enter Shaft No. 12, and proceed thence to the Hana-

han Pumping Station. By this means, it is possible to unwater and inspect that section of the tunnel between Shaft No. 12 and Shaft No. 7—a distance of a little over five miles. Further, water can be diverted from Shaft No. 5 by natural channel to the Ashley River, and inspection had of the tunnel from Shaft No. 7 to Shaft No. 5—a distance of two miles. If desired, water can be diverted from Shaft No. 20 into the Goose Creek Reservoir, and the section from Shaft No. 20 to Shaft No. 22, a distance of a little over two miles, can be inspected. In addition to this, all shafts are provided with grooved slots so that stop logs can be inserted and any section of the tunnel can be unwatered and inspected.

Installed at the intake shaft, and also at shafts No. 7, 12, 20 and 22, were Stevens automatic recording gauges and charts which record the water level in the river and in the tunnel shaft. From the information obtained from these charts, and knowing the gate openings at the intake, we can calculate very closely the total water passing through the tunnel. By construction of the loss of head curve from the readings on these gauges, we can determine immediately if any obstruction occurs in the tunnel between the gauges. Needless to say no such obstruction has occurred to date, after four years of service.

When water was first turned into the aqueduct, there was a measurable increase in the alkalinity between the raw water at the intake and the water at the outlet shaft No. 22. This gradually decreased until, at the present time, there is very little, if any, increase in alkalinity. Our explanation of this is that after construction there was a material quantity of bruised and disintegrated marl on the surface of the tunnel, which rapidly went into solution; but since this has been dissolved, there has been formed a more or less impervious coating which is dissolving very, very slowly, the rate of solution with the present flow being immaterial. We are operating the tunnel at about 30 m.g.d., or at a velocity of 1.16 f.p.s., requiring about 30 hours of flow from the intake to the outlet shaft.

Costs. The total cost of the first 4½-mile section of the tunnel, built by contract in 1928-29, was $387,635 which included:

Engineering	$ 24,042
Lands and rights-of-way	8,997
Legal expenses, searching of titles, recording deeds	1,206

Construction including material purchased by the Commission and furnished to the construction company 353,390

The unit cost, therefore, was $16.32 per foot.

The cost of the 18.61 miles constructed in 1936-1937 by our own forces was $976,206, or a little less than $10 per foot, including engineering, lands, rights-of-way, inspection, material, labor and equipment. There was a slight reduction in this cost however due to the salvaging of the machinery.

Outstanding features. 1. The driving of a 7-ft. diameter, modified horse-shoe shaped tunnel at an average depth of 40 ft. below mean sea level, entirely through marl formation, for a total distance of 23.11 miles, 18.6 miles of this tunnel being constructed in a little less than ten months.

2. Although the tunnel is unlined because of the nature of the marl through which it is driven, it is capable of delivering 55 m.g.d. of water by gravity from the Edisto River to Goose Creek Reservoir, with a fall of only 18 ft. in 23.1 miles; and by pumping under normal suction lift from the terminal shaft, its capacity can be increased to 80 m.g.d.

3. The prosecution of construction under direction of the department without resorting to public letting which we figure would have meant a delay of at least 90 days.

4. Workmen's compensation insurance being carried by the department with a saving of something over $50,000 in total cost for insurance alone. The most serious injury during the entire construction was the loss by one workman of the first joint from four fingers of his left hand.

5. The combination contract between a private corporation and a municipal corporation for the construction of such a project and the delivery to the private corporation of a minimum quantity of water over a period of 50 years.

In closing I want to express my appreciation to the staff of Mr. Malcolm Pirnie, Consulting Engineer of New York City, to Mr. James R. Sanborn, Consulting Engineer, to Mr. Robert E. Parker of New York who acted as superintendent and engineer of construction, to the officers of the West Virginia Pulp and Paper Company for their

coöperation in the undertaking, and to Mr. McDowell and his assistants for their work in connection with the tunnel; also to Mr. J. R. Inman for preparation of drawings accompanying this paper.

REFERENCES

Earl Sloan, State Geologist, "Catalogue of the Mineral Localities of South Carolina".

C. W. Cooke, U. S. Geological Survey Bulletin 867, 1936.

Charles P. Berkey, Geologist, New York City—Report to Mr. Malcolm Pirnie, March 11, 1936.

Joe Henry Watkins, "Origin of the Phosphates of South Carolina."

Compressed Air Magazine, Vol. 42, No. 4—April, 1937.

Water Works Engineering, Vol. 90, No. 10—May 12, 1937.

Engineering News-Record, Vol. 119, No. 2—July 8, 1937.

PROCEEDINGS

November 1941 Meeting

Hotel Statler, Boston, Mass.

Tuesday, November 25, 1941

President Francis H. Kingsbury in the chair.

Samuel M. Ellsworth read a letter sent to him under date of October 16, 1941, by John Bowman, City Water Engineer, Edinburgh, Scotland. Following this, he read a paper entitled "British Waterworks Practice in Time of War," by Mr. Bowman which was to have been delivered at the September convention but was not received in time for such delivery.

Secretary Gifford announced the election by the Executive Committee of the following:

Members: Edward M. Calahan, Superintendent, Water Filtration Plant, Pawtucket, R. I.; William H. Moody, General Manager, Naugatuck Water Company, Naugatuck, Conn.; David D. Eames, Consulting Engineer, Arlington, Mass.; Henry U. Cormier, Jr., Filtration Plant Operator, Athol, Mass.

Junior: Albert C. Reppucci, Student M.I.T., Boston, Mass.

A paper "Experiments with Tube-Loy Pipe" was read by Robert Spurr Weston, of Weston and Sampson, Consulting Engineers, Boston, Mass.

A paper "Salt Content of Wells in Massachusetts Affected by the Tidal Wave and Hurricane of 1938" was read by Vincent M. Hynes, Massachusetts Department of Public Health.

A paper "The World's Largest Filtration Plant" was presented by John E. Gayton, student at M.I.T., of Chicago, Ill. The paper was followed by the showing of colored motion pictures of the layout and construction of the South District Plant, Chicago, Ill.

DECEMBER 1941 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, December 18, 1941.

President Francis H. Kingsbury in the chair.

Secretary Gifford announced the election by the Executive Committee of the following new member: Edmund Horace Sargent, Superintendent, Water Department, Wilmington, Mass.

AMENDMENTS TO THE CONSTITUTION

The following amendments to the Constitution were proposed and presented to the Executive Committee by the Committee on Revision of the Constitution. In accordance with Article IX of the existing Constitution, these amendments were presented for the consideration of the Association and were approved at the December meeting of the Association:

ARTICLE II

Section 1. Amended so as to read: The Association shall consist of Members, Honorary Members, Juniors, Associates and Corporate Members.

Section 4. Amended by striking out the entire section and substituting therefor the following: Unless otherwise qualified the word "Member" as used in this Constitution shall mean a Member as defined in Section 2 of this Article.

Section 8. Amended so as to read: Members of all grades shall be entitled to all the privileges of the Association except the right to vote or to hold office, which right shall be vested in the grade of Member; provided, however, that Honorary Members elected from the Members of the Association, shall not thereby lose the right to vote or to hold office.

Section 10. Amended by striking out the entire section.

ARTICLE III

Section 1. Amended so as to read: Honorary Members shall be proposed by at least ten members, and shall be elected by a unanimous vote of the Executive Committee.

ARTICLE IV

Section 2. Amended so as to read:

Annual Dues shall be as follows:

Members	$ 6.00
Honorary Members	No dues
Juniors	3.00
Associates	20.00
Corporate Members	10.00

ARTICLE V

Section 1. Amended so as to read: The officers of the Association shall be a President, two Vice-Presidents, three Directors and a Treasurer. The President and the Treasurer shall be elected for terms of one year each, and there shall be elected each year a Vice-President for a term of two years and a Director for a term of three years. The term of each elected officer shall begin at the close of the Annual Convention and shall continue until a successor is elected.

ARTICLE V

Section 5. Amended by striking out the entire section.

ARTICLE VI

Section 4. Amended so as to read: The Treasurer, under the direction of the Executive Committee, shall have the custody and the investment of all funds of the Association, and shall file a surety bond in a form and in an amount to be determined by the Executive Committee, the premium on said bond to be paid by the Association. He shall pay all bills or other indebtedness of the Association when properly approved by the President. All orders for withdrawals of funds and checks for disbursements shall be signed by the Treasurer and countersigned by the President. The Treasurer shall keep accurate records of all receipts and disbursements and of all property of the Association in his charge, and shall render a report of the same at the Annual Convention. In the event of the incapacity of the Treasurer to discharge the duties of his office, the Executive Committee may appoint another to act in his stead and be designated as Assistant Treasurer. Such appointee shall be bonded in the same manner as required for the Treasurer. All officers, appointees and employees of the Association who handle funds shall be bonded, the premiums on said bonds to be paid by the Association.

Section 9. Amended so as to read: The proceedings of the Association shall be published as the "Journal of the New England Water Works Association", and shall be issued quarterly under the direction of the Executive Committee. The Journal shall contain Memoirs of deceased members.

ARTICLE IX

Amended by striking out the entire article and substituting therefor the following:

COMMITTEES

Section 1. In addition to the Executive Committee and the Finance Committee as defined in Article V, the Executive Committee shall from time to time appoint nontechnical committees as in its discretion it may determine, and a Committee on Library to have general charge of the Library of the Association.

Section 2. Professional and technical committees, which shall make studies, investigations and reports to the Association, shall be appointed by the Executive Committee or as otherwise directed by vote of the Association. Such committees shall continue until they are discharged by the Executive Committee.

Section 3. The Executive Committee at a meeting to be held in October of each year shall appoint the members of all standing professional and technical

committees of the Association or shall delegate the duty of appointing any or all of such committees to the President. A list of all such Committee members shall be forwarded to each committee member by the Secretary in November. In case such appointments are made by the President, he shall notify the Secretary of his appointments on or before the first week in November. During the month of November, the Secretary shall send a list of committee members to the Editor of the Journal, who shall arrange for its publication in the December issue of the Journal. Interim committee appointments shall be made by the Executive Committee or as otherwise directed by vote of the Association, and notification of such committee members shall be made by the Secretary within fifteen days after their appointment.

Section 4. The Executive Committee may appoint committees to draw up or consider specifications for adoption by the Association, either for the Association alone or in cooperation with other associations, or societies. Each committee so appointed shall report to the Executive Committee such draft of specifications as it may recommend. The Executive Committee may then accept or amend such draft and submit it to the Association for its approval. Only after approval by the Association at a regular meeting shall specifications be published as approved by the New England Water Works Association.

ARTICLE X

New Article: Formerly Article IX of the present constitution.

ARTHUR L. SHAW. Mr. President, I have a resolution that I should like to offer to the Association. Before doing so I should like to read a statement which will explain why the resolution is offered:

At 4 p.m. on December 9, 1941, at the time of the first air raid warning issued in New England since the outbreak of hostilities with Japan, the following advice to householders was broadcast by radio:

"Two or three buckets filled with water, a stirrup pump or hand fire pump for water should be available. Keep bathtub filled with water to replenish buckets quickly."

The implications of this advice are contrary to British practice, as indicated by the following excerpts from British publications:

"The importance of conserving water in emergency fire fighting cannot be over-emphasized. The provision of adequate supplies of water is one of the most difficult problems in the whole of the Emergency Fire Organization, and everything possible should be done by officers in charge of fire parties, and by individual firemen, to avoid any unnecessary waste of water, especially in the case of water from the mains." ("Memorandum on Emergency Water Supplies for Fire Fighting," issued by the Home Office of the Fire Brigades Division and the Scottish Office, under date of April, 1939.)

"An independent source of water supply should be arranged in case water mains are damaged or the pressure of water in them is reduced owing to fire brigade activities elsewhere. For this purpose water should be stored beforehand in tanks or buckets or used bath water may be retained in the bath during periods of heavy raiding." ("Air Raids—What You Must Know and What You Must Do", Manual of 1940, Ministry of Home Securities.)

Attention is called to the fact that, in this reference, the water in the bath tub is water that has already been used, and no waste is involved in retaining it in the tub.

"The storage cistern in connection with a hot water supply provides a small reserve stock of water, which in case of emergency, will be most valuable. Householders, especially those who are not provided with hot water supply systems, are advised to store and reserve a small stock of water for drinking, cooking, extinguishing of fire, bucket flushing of water closets and other essential purposes.

"Where springs and wells are in close proximity to the dwellings, reserves can be drawn from these sources for extinguishing fires and bucket flushing of water closets, but not for drinking or cooking purposes.

"Great care should be taken to put water reserved for drinking and the preparation of food into suitable and clean vessels. The remainder of the stock might be kept in wash tubs, buckets, etc. The fixed bath should not be used to store clean water—it is much too wasteful. On an air raid warning being given, do not draw any water except in case of dire necessity." ("A.R.P. and Water Undertakings," Institution of Water Engineers of England, dated July 19, 1940.)

"Many householders acting on the advice of the Ministry of Home Security to keep the bath full for fire-fighting purposes fill the bath each night and empty it again in the morning. This erroneous interpretation has resulted in a very serious waste of water. What was intended was that used water should be left in the bath until the bath is next required." ("Water Supply Under War Conditions," Water & Water Engineering, February, 1941.)

"In connection with A.R.P., a government department recommended householders to fill baths and buckets so as to have a reserve of water for extinguishing fires if the supply should be interrupted. Obviously if this were done in thousands of houses when an alert was sounded there would be such a heavy draw on the mains as to reduce the pressure for the official fire brigades. It was subsequently explained that used water should be kept and would prove as effective as clean." ("Civil Engineers and the War," published in Water & Water Engineering, April, 1941.)

Furthermore, the Manual on Emergency Sanitation of the Massachusetts Committee on Public Safety, among the sponsors of which were two members of the New England Water Works Association,

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Furthermore, the Manual on Emergency Sanitation of the Massachusetts Committee on Public Safety, among the sponsors of which were two members of the New England Water Works Association,

gives advice contrary to that broadcast on December 9. The following is quoted from that manual:

"In times of danger of air raids, consumers should be given instructions relative to the conservation of water. No water should be drawn in times of air raid warnings except in case of dire emergency."

In addition to the fact that the broadcast advice was contrary to good practice, it is particularly important to conserve water at this time of extreme drought. Unnecessary use of water must be discouraged. It seems evident, therefore, that this Association should take effective steps to offset the advice broadcast on December 9. After discussion, the following Resolutions were adopted:

WHEREAS, it has been brought to the attention of the New England Water Works Association that erroneous and misleading advice has been broadcast recently relative to the use of water by householders at times of air raid warnings,

BE IT RESOLVED THAT the New England Water Works Association recommends to the authorities in charge of emergency precautions the advice given in the Manual of Emergency Sanitation, of the Massachusetts Committee on Public Safety, as follows:

"In times of danger of air raids, consumers should be given instructions relative to the conservation of water. No water should be drawn at times of air raid warnings except in case of dire emergency."

BE IT FURTHER RESOLVED THAT this recommendation of the Association be given as widespread publicity as possible through the press and by such other appropriate methods as may be available, and that those responsible for the December 9 broadcast be advised of the action.

A Symposium: The 1941 Drought and Its Effect on Water Supplies, was opened by H. B. Kinnison, District Engineer, U. S. Geological Survey, Boston. Representatives of the New England States discussed the matter, as follows: Leonard W. Trager, Associate Sanitary Engineer, New Hampshire Board of Health; Edward L. Tracy, Director, Division of Sanitary Engineering, Vermont Department of Public Health; Walter J. Shea, Acting Chief, Division of Sanitary Engineering, Rhode Island Department of Health; Warren J. Scott, Director, Bureau of Sanitary Engineering, Connecticut Department of Health; Ralph M. Soule, Assistant Sanitary Engineer, Massachusetts Department of Public Health.

A sound moving picture in color, "The Construction of the Inlet-Outlet System of the Stone Canyon Reservoir," prepared by the Los

Angeles Department of Water and Power, was presented through the courtesy of the Barrett Company.

JANUARY 1942 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, January 15, 1942

President Fancis H. Kingsbury in the chair.

The President announced the death of two members: Alexander O'Brien of Holyoke and George F. Merrill of Ware.

Secretary Gifford announced the election by the Executive Committee of the following new members: Harold J. Baker, Superintendent, Water Department, Fishers Island Farms, Inc., Fishers Island, N. Y., William Charles Paxton, Superintendent, Public Works, Lexington, Mass., James W. Reilly, Superintendent, Water Works, Ware, Mass., Edward S. Duarte, Superintendent, Water Works, Tisbury, Mass.

Harold L. Brigham in the chair.

Richard H. Ellis and G. N. Ricker of the Factory Mutual Fire Insurance Companies presented a film entitled "They're Dropping Incendiaries."

A paper, "Forest Management to Control Water Supplies," was read by William Mollenhauer, Jr., Forester, U. S. Forest Service.

A paper, "Design and Construction of Preload Tanks and Domes," was read by Andrew C. Linbeg, Vice-President of the Preload Company.

FEBRUARY 1942 MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, February 19, 1942

President Francis H. Kingsbury in the chair.

Secretary Gifford announced the election by the Executive Committee of the following members: Harry J. Brillhart, Framingham, Mass.; Canfield Smith Dickie, Pittsfield, Mass.; Earl Roy Perry, Worcester, Mass.

ARTHUR C. KING. Mr. President, the Massachusetts members

of the Association will be interested in a law that was just enacted at the special session this winter. In substance this law says that if the Department of Public Health determines that during the existence of the present state of war it is necessary for a city, town, district, or water company maintaining water supply to provide equipment for such supply including exchange of equipment or any addition to the existing equipment for the protection of public health, said department may order such city, town, district, or water company to provide such equipment or to make such additions to any existing equipment.

The Supreme Judicial or Superior Court shall have jurisdiction in equity to enforce any such order.

A motion by Harold N. Griswold was put and carried that the Tentative Specifications for Sluice Gates as approved and printed by the American Water Works Association be approved by the Association.

HORACE L. CLARK presented the following resolution on the question of furnishing tires for the cars of superintendents and other water works officials to be used for water works service only:

WHEREAS the supplying of water for domestic, sanitary and fire protective purposes is the most essential of all public services in a community, and is absolutely necessary at military and naval establishments, and vital defense areas, and

WHEREAS the failure of this service in any of these areas means total cessation of all activities and eventual evacuation, and

WHEREAS the immediate presence of the superintendent or other operating official at scenes of disaster to the water supply system is essential for quick repair and for the continued normal operation of the utility, and

WHEREAS under the rulings of the Tire Rationing Board, tires and tubes are not available for purchase for the automobiles used by such officials, therefore be it

RESOLVED that the New England Water Works Association respectfully petition the Tire Rationing Board that the said rulings be amended so as to permit the purchase of tires and tubes for automobiles of such operating officials to be used only in the performance of their duties.

The motion was carried unanimously.

A paper, "Coördinating the Fire Service," was read by Percy C. Charnock, State Fire Coördinator for Massachusetts, and discussed by Francis H. Kingsbury, Fred J. Reny, Henry E. Halpin, and D. M. Sullivan.

Joel W. Eastman, Esq., gave a talk on "Our Present Obligations."

A sound motion picture entitled "Warning," showing an air raid in England and the activities of the organized civilian defense was presented.

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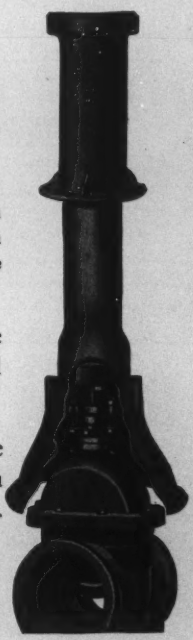

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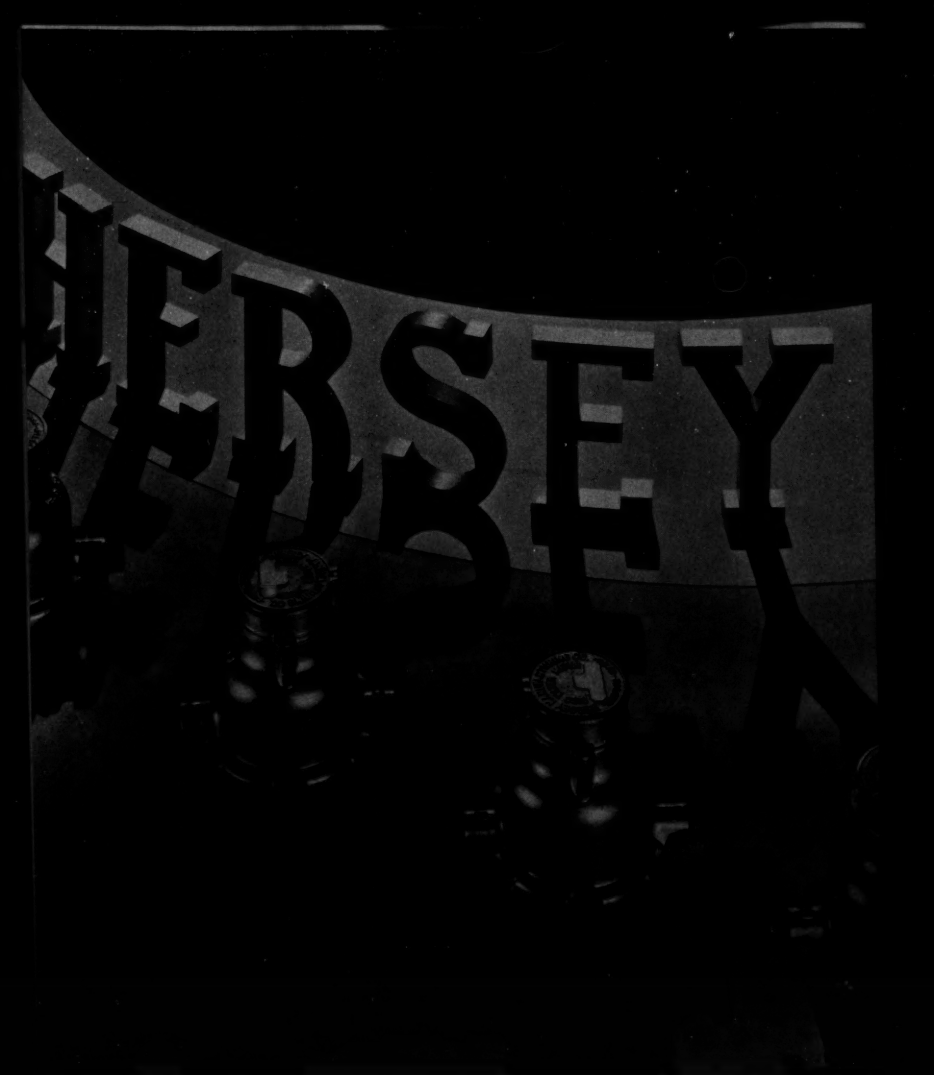

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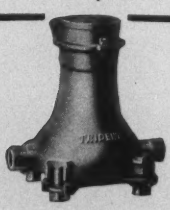

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General Offices: HARRISON, NEW JERSEY
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in your selection of Service Pipe
Eliminate the danger of metal poisoning and at the same time eliminate corrosion.
Specify EUREKA Cement Lined Pipe
IMMEDIATE DELIVERY TO WATER WORKS
EUREKA PIPE COMPANY, Inc.
MANUFACTURERS OF
Centrifugal Cement Lined Pipe — Lead and Tin Fittings
591-593 WASHINGTON ST. TEL. 3-9550 LYNN, MASS.

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

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National Water Main Cleaning Co.
30 Church Street New York City

Cement Lined Service Pipe
Cement lined pipe has eliminated corrosion and metal contamination for 60 years
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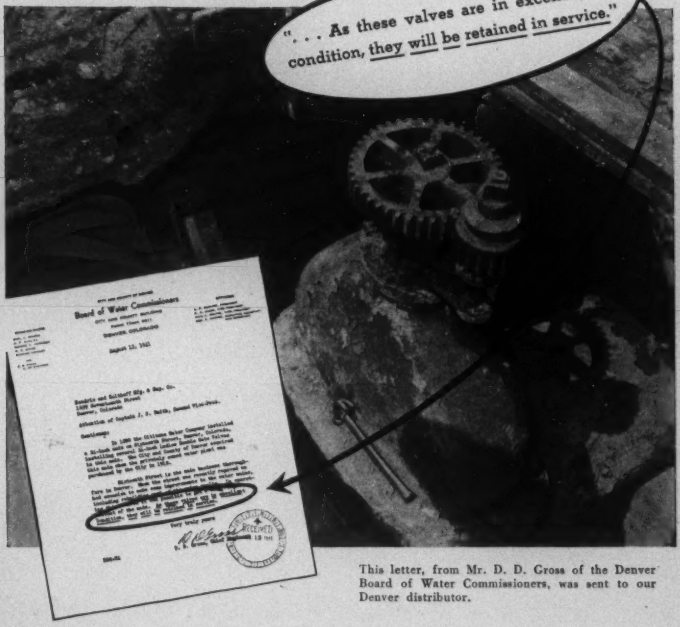

This letter, from Mr. D. D. Gross of the Denver Board of Water Commissioners, was sent to our Denver distributor.

In the year 1890, a number of Ludlow Valves were installed in a 24" water main under Sixteenth Street, Denver, Colorado.

In 1941, the valve vaults were opened and the valves tested. They were *found to give watertight shut-off of the main.* Since the valves are still in excellent condition, "they will be retained in service."

Longer life and low maintenance costs are only two of the reasons why many water works departments standardize on Ludlow Valves. In addition, the double-disc parallel seat principle which Ludlow developed and perfected assures easy operation at all times, positive closure and self-cleaning seats. Send for catalog No. 201 which fully describes Ludlow Valves and Hydrants.

LUDLOW VALVES

THE LUDLOW VALVE MFG. CO., INC., TROY, NEW YORK

TIGHT JOINTS

REGARDLESS OF PIPE SIZE OR SOIL CONDITION

UNDER all conditions of service cast iron water mains can be laid with assurance of permanently "bottle-tight" joints if HYDRO-TITE is used as the jointing compound.

No matter how large or small the pipe nor how tough the going may be, HYDRO-TITE will prove the easiest and most economical to use.

HYDRO-TITE has a record of more than a quarter century without a failure anywhere.

A Symbol of Quality

A Dependable Self-Caulking Joint Compound

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

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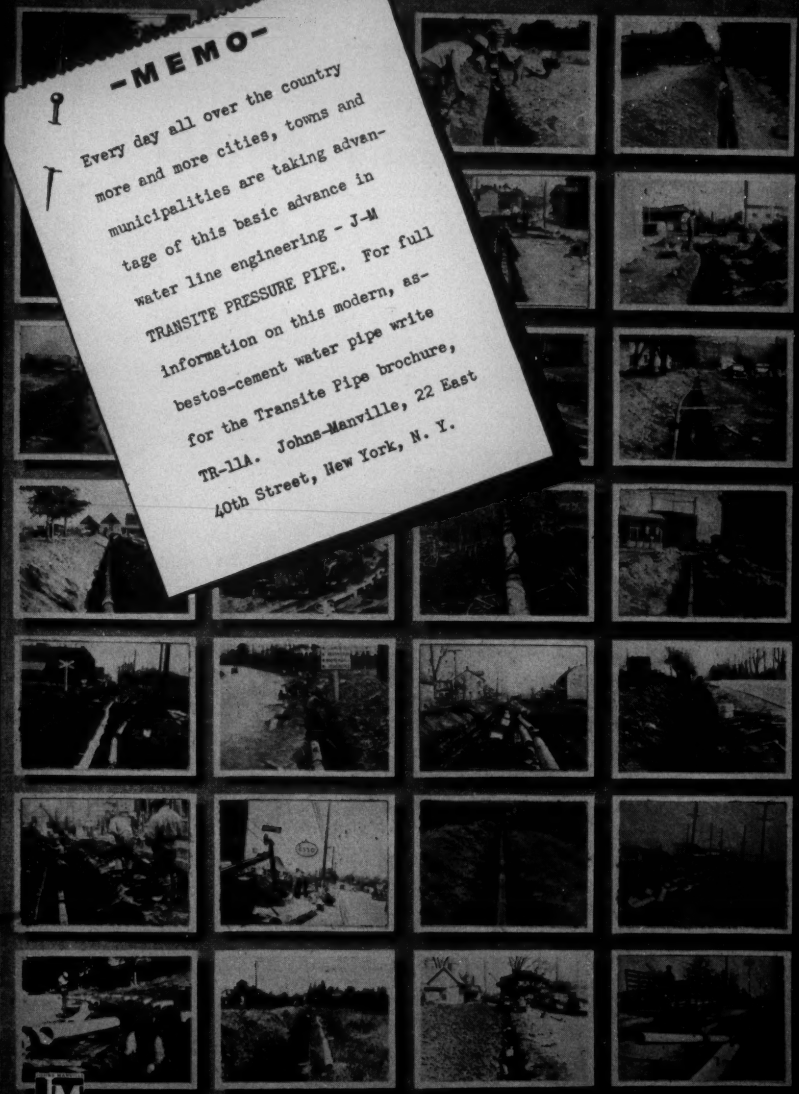
-MEMO-
Every day all over the country more and more cities, towns and municipalities are taking advantage of this basic advance in water line engineering - J-M TRANSITE PRESSURE PIPE. For full information on this modern, asbestos-cement water pipe write for the Transite Pipe brochure, TR-11A. Johns-Manville, 22 East 40th Street, New York, N. Y.
JM
Johns-Manville TRANSITE PRESSURE PIPE

HOW COMPLETE
ARE YOUR REFERENCE FILES?

EXTENSIVE LITERATURE ON TURBINE, POWER, SPLIT CASE AND BUILTOGETHER CENTRIFUGAL PUMPS IS AVAILABLE TO YOU — TOGETHER WITH REMARKABLY DETAILED BULLETINS ON THE MOTORS AND DIESELS THAT DRIVE THESE PUMPS.

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Write to

FAIRBANKS, MORSE & CO.

178 Atlantic Avenue **Boston, Mass.**

Soon to be started: Installation of still another Fairbanks-Morse Diesel-driven Pump, this time for the Exeter, N. H., Water Company.

FAST WORK ... with new 18-foot lengths of "Century" Pipe laid at rate of 8 feet per minute in Media, Pa.

Media, Pa., recently installed a pressure line, using Keasbey & Mattison "Century" Asbestos-Cement Pipe in the new 18-foot lengths. The time required to lower and couple the first 396 feet was 49½ minutes . . . a speed of exactly 8 feet per minute.

Naturally, installation time varies with the conditions and with the workmen's skill, but the new 18-foot lengths of "Century" Pipe invariably save time and cost. 28% fewer joints are needed . . . 113 fewer joints per mile of line. These new long lengths, which are now furnished in 6" and 8" sizes, class 150, are especially desirable for use on long stretches of line. However K&M 13-foot lengths are available for those cases where trench conditions make shorter lengths of pipe more advantageous. Let our representative recommend the correct length for your requirements.

"Century" Pipe never tuberculates, never corrodes. It has a lastingly smooth interior. It is light in weight for easy, low-cost handling. Its "Century" Flexible Couplings provide tight joints, and permit installing a line in a curve of large radius without using elbows or bends. Write Dept. 1017 for free booklet, "Mains without Maintenance."

Mr. G. D. Houtman, C. E., Member of the Media Council, Chairman of the Water and Sewer Committee, and Assistant County Engineer. Mr. Houtman says, "Our long experience with asbestos-cement pipe has shown us its many advantages. In the new 18-foot lengths, 'Century' Pipe is even more economical."

KEASBEY & MATTISON
COMPANY, AMBLER, PENNSYLVANIA

Make your own comparison

IMPORTANT FIRE HYDRANT REQUIREMENTS	Kennedy SAFETOP	Your Present Hydrants
What is the inside diameter of the standpipe?	7-in. on 4-in. size 8½-in. on 5-in. size	
Has the hydrant a quick-repair section to limit collision damage?		
How many hydrants with this feature are in service?		
If broken by a colliding vehicle— What is the cost of repair parts? How long does it take to replace them? How many men are required to make the necessary repairs? Is any excavation necessary for repairs?	$6.00 About 15 min. One Man No	
Must the water pressure be shut off to permit repairs?	No	
Has the hydrant a flange at the ground line which might be broken by frost upheaval?	No	
Can the nozzles be rotated to the exact desired position without excavation or shutting off the water supply?	Yes	
Is the hydrant adjustable to change of grade without excavation or shutting off the water pressure?	Yes	
Has the hydrant rust-proofed bolts and studs and bronze nuts at the cover and stuffing box?	Yes	

The above tabulation indicates some of the many superiorities of Kennedy SAFETOP Fire Hydrants that have won the enthusiastic approval of water department superintendents. In addition, the simple straight line operating mechanism with compression type inlet valve, the long-wearing valve facings, the ease of operation and adjustments, the low pressure loss, and thorough dependability of Kennedy SAFETOPS warrant your investigation before you make your next hydrant purchase.

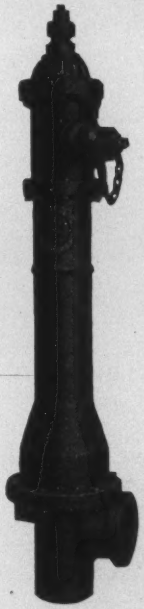
The Kennedy Valve Mfg. Co., Elmira, N. Y.

KENNEDY SAFETOP FIRE HYDRANT

REG. U.S. PAT. OFF.

EDDY

Valves and Hydrants



Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced.

. . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

Eddy Valve Co.

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Every atom pure lead

For calking pipe joints under the most difficult conditions.

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For rust-proofing tanks and pipes.

Write for Water Works specifications.

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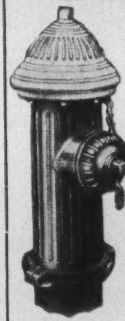
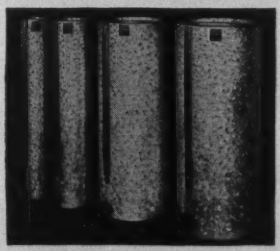
THE A. P. SMITH MFG. CO.,
East Orange, New Jersey



Manufacturers of high-grade specialties in connection with water and gas department work, consisting of—
Machines for inserting valves under pressure, and for making large right angle connections to mains under pressure, and for inserting house service connections under pressure.
Also makers of—
Pipe Cutting Machines, each size being adjustable for use on three different sizes of pipe.
High-grade water works supplies, such as Hydrants, Valves, Meters, Corporation Cocks, etc.
We also make a new type of hydrant which has a breakable joint at the ground line which when struck with an impediment will break at a specified point and only a coupling has to be used to repair the hydrant, which will be back in service in twenty (20) minutes.
"HYDRANT WITH BREAKABLE COUPLING"

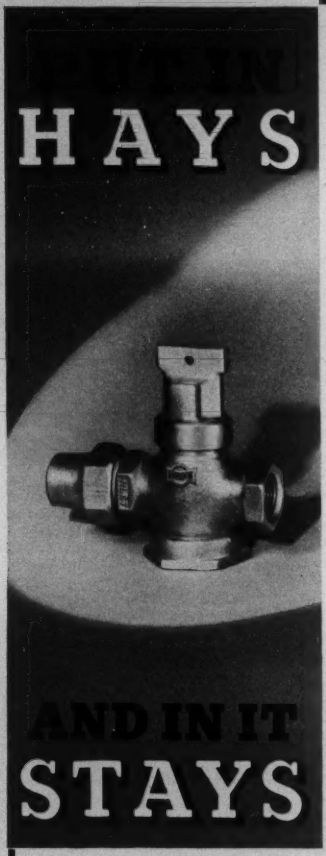
SMITH
WATER WORKS SPECIALTIES & SUPPLIES
THE A.P.SMITH MFG.CO. *East Orange,N.J*

Ford Calibrated TESTING TANKS



These tanks are made in four sizes. They are heavily galvanized and provided with percentage calibration, gauge glass and quick-opening drain valve. Simple and easy to use. Hundreds in use. Write for information.

The Ford Meter Box Co.
WABASH, INDIANA



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MUCH of the early brass made by Hays over seventy years ago is still in service. The reason can be found in one word: QUALITY. Starting with correct technique and close control in the foundry, all operations right down the line through tapping, machining and testing are performed with but one thought in mind: *To make Hays the best water works goods available.*

Hays makes New England Pattern water works products that are fully interchangeable with what you are now using. Place your next requirements with Hays and eliminate service failures.

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FOR 73 YEARS A GOOD NAME IN WATER SERVICE BRASS GOODS

COPPER • BRASS • LEAD • IRON

HAYS *Water Works* PRODUCTS

HAYS MFG. CO., ERIE, PA. • *Since 1869*

What's in the FUTURE?

We wish we could find a reliable crystal to tell us.

But this we know—and it doesn't require a crystal ball to see. The time will come when Uncle Sam will say to us, "Well, boys, the nightmare is over. We don't need you any more. Now run along, and 'tend to your own knitting*".

Until that time, our ability to serve you is necessarily limited by the demands of our war efforts.

But when that time comes (and may it come soon), will you please remember that we have even increased our skill in designing and building the kind of centrifugal pumps that have made Morris installations win high praise and repeat orders in every industry.

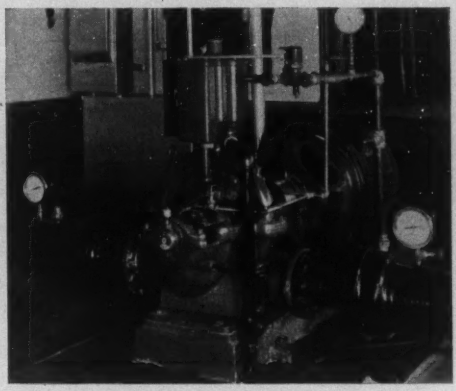
* Making centrifugal pumps and hydraulic dredges
—the best in the world, we think.

STARKWEATHER ENGINEERING CO. **MORRIS** ESTABLISHED 1864 NEWTON, MASSACHUSETTS

CENTRIFUGAL PUMPS

DE LAVAL

Automatically Primed Centrifugal Water Works Pump



Town of Brookline — West Roxbury Station

The above unit is fitted with the patented De Laval Class 1 Submerged Suction Priming System. It supplies water for filter sand washing. The ¾" corporation cock, shown in the suction piping, can be opened fully, with the pump in operation, causing complete cessation of delivery and the pump will reprime itself and again deliver water within one minute after closing the corporation cock. The entire system is completely automatic and is supplied integrally with the pump. It incorporates safety devices within the priming chamber. May we explain our system to you in greater detail?

TURBINE EQUIPMENT COMPANY OF NEW ENGLAND

80 Federal Street **Phone LIBerty 5993-5994** **Boston, Mass.**

New England Representatives for

DE LAVAL STEAM TURBINE COMPANY
TRENTON, NEW JERSEY

Mobile Protection

FOR WATER SUPPLIES

HERE'S THE NEWEST CONTRIBUTION of W&T engineering to public health defense ... a trailer-type mobile chlorinating unit, designed to provide positive protection of water supplies under emergency conditions, or to meet any need for closely controlled chlorination "on location" without delay.

Using the dependable W&T vacuum principle, the unit provides for solution feed of chlorine over a wide range of application rates up to 100 lb. of chlorine per day. Self-powered by a gasoline motor, it will draw injector water from an open source or pipe line, and apply the chlorine in the main against pressures as high as 100 lb. per sq. in. Two 150 lb. chlorine cylinders are cradled in the trailer, connected to assure continuity of supply. Hoses, cocks, tools and other accessories for making emergency main connections are provided.

Data and experience gained by W&T technical experts in England during the past year, backed by W&T's continuous experience with emergency chlorination equipment extending from before the last World War, are reflected in the design and construction of the unit.

Both trailer frame and chlorinator are designed to stand up under the strenuous conditions of transport and service which exist during emergencies when faithful performance is most essential. Construction is exceptionally rugged to provide ample strength for rigorous duty.

SA 120A

WRITE TODAY FOR COMPLETE STORY

W&T *"Technical Publication 228"* describes the new Emergency Chlorination Trailer in detail.

New booklet *"A Sound Defense for Your Water Supply"* gives 7 point plan for total protection, including data on emergency chlorination. Ask for W&T Technical Publication 225.

The assistance of W&T Representatives who are specializing in emergency protection plans is also available without obligation. Just call your local W&T Representative or write direct to:

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN CO., Inc.

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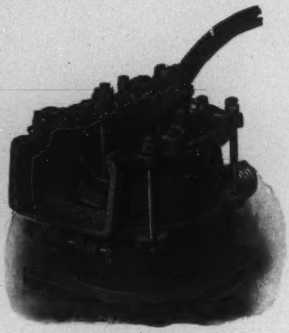
EDSON
PUMPS and ACCESSORIES



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NO TUBERCULATION OR INCRUSTATION
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Recent Repeat Flow Test Shows High Williams Hazen Coefficient Unchanged After EIGHT YEARS

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Attend A.W.W.A. Convention at Stevens Hotel, Chicago, Illinois, June 21-25, 1942

Ask for Catalogue G

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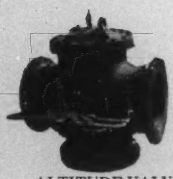
Sales Manager, New England Branch
3 WASHINGTON SQUARE HAVERHILL, MASSACHUSETTS

1879—ROSS— 1879

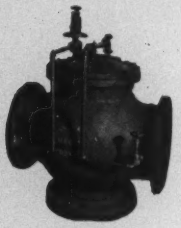
AUTOMATIC VALVES



Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE

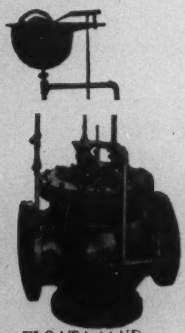
1. Single Acting
2. Double Acting



Maintains desired discharge pressure regardless of change in rate of flow

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

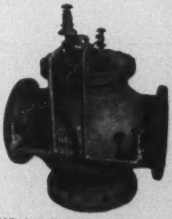
FLOAT VALVE

A self contained unit, with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.

Maintains safe operating pressures for conduits, distribution and pump discharge



SURGE-RELIEF VALVE

Electric remote control—solenoid or motor can be furnished

REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

ROSS VALVE MFG. CO., INC. Box 592 TROY, N. Y.

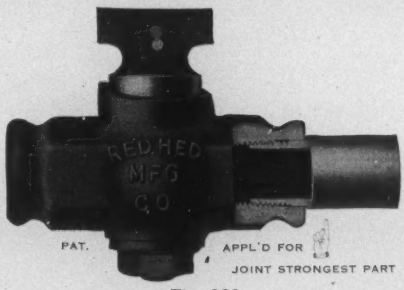


Fig. 220

TEE HEAD RECESSED STOP AND WASTE

A thoroughly dependable Tee Head Stop with or without Waste for use with either wrought iron or brass pipe. No coupling required for attaching RED HED RECESSED Stops to service pipes.

Reenforced rings cast on each end of RED HED Stops, increases strength of joints.

We also manufacture RED HED RECESSED Fittings.

RED HED MFG. CO.

Manufacturers of

RED HED Brass Goods for Water Works

368 Congress Street Boston, Mass.

"EASY AS FIXING A MATHEWS HYDRANT, ISN'T IT?"

Changing a tire and replacing a Mathews Hydrant are very much alike. Just remove the "works" and replace it with a spare. In a Mathews Hydrant the barrel contains all working parts including main and drain valve seats. It unscrews from the elbow, lifts out through the loose protection case and means that *you never have to dig a properly set Mathews Hydrant.* Fire protection is vital in war time. Give your community the speedy repair, the frost protection, the absolute dependability, and the permanent economy of Mathews Hydrants.

MATHEWS HYDRANTS

Made by R.D. WOOD Company

400 CHESTNUT STREET, PHILADELPHIA, PA.

ESTABLISHED IN 1803

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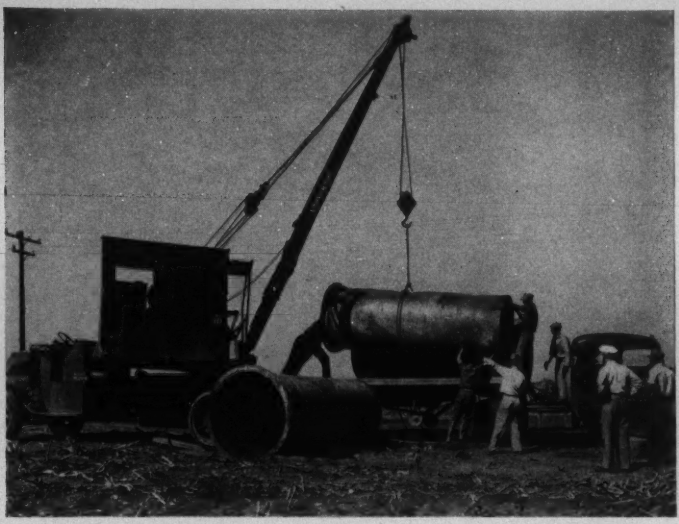

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